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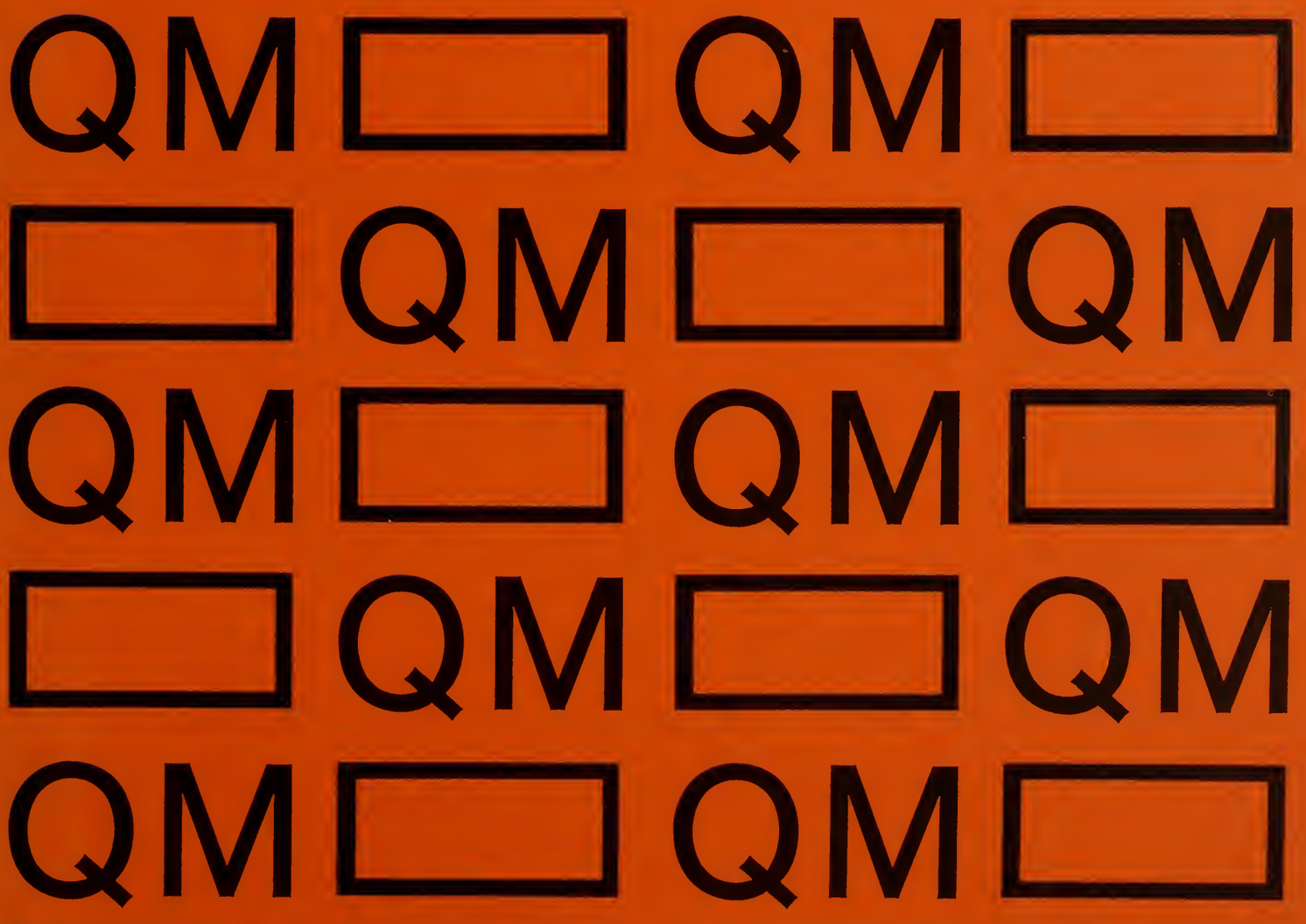
Quality Management Manual

For Fossil Fuel Steam Electric Generating Plants



FOREWORD

REA has developed a series of bulletins designed to assist power supply cooperatives in increasing the availability of their power plants. The need for increasing plant availability is apparent to all. A number of methods may be applied to achieve this goal. One way that this can be accomplished is by improving the quality of the plant through an effective Quality Management Program.

This manual is intended to assist borrowers in establishing and administering a quality management program for fossil fuel steam electric generating plants. It discusses and explains quality management methods and provides guidance on the development and implementation of a cost-effective Quality Management Program. It also gives suggestions on how to evaluate the effectiveness of such a program.

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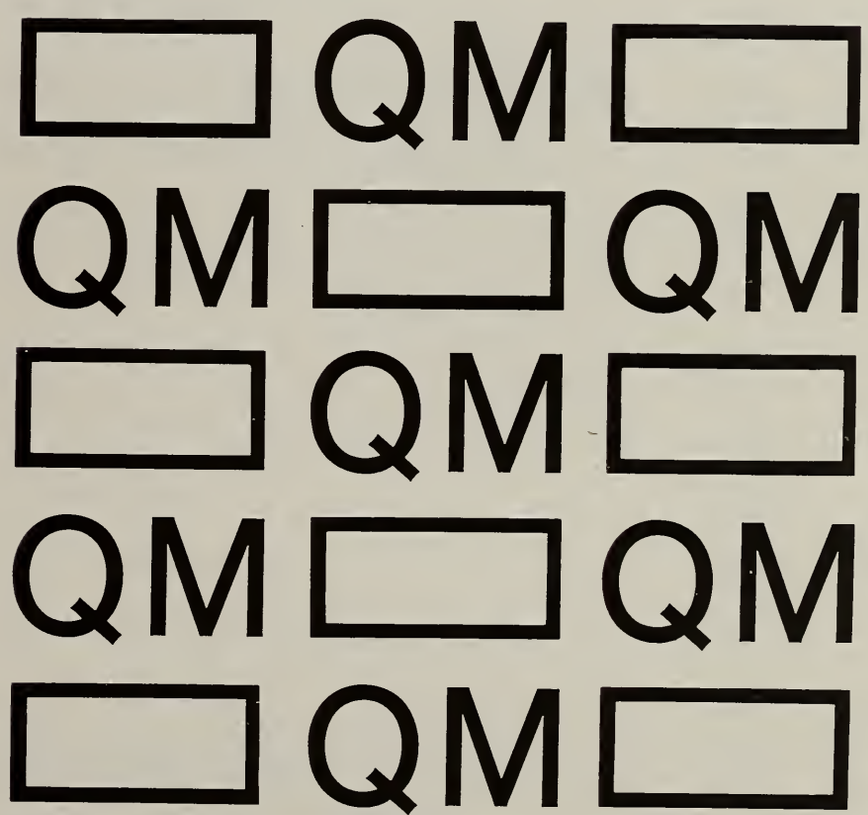

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SECTION I

INTRODUCTION

A. OBJECTIVE AND SCOPE OF THIS MANUAL

1. OBJECTIVE

The objective of this manual is to improve the availability of REA-financed power plants through improved quality management practices. The increased cost and complexity of modern fossil fuel power plants require greater assurance that plants will be available for power generation during the course of their lifetime. One way that greater plant availability can be achieved is by improving the quality of the plant. Quality management can help accomplish this by preventing or detecting and correcting deficiencies in a cost-effective manner. This manual describes various techniques which can achieve the objective of increased plant availability for your organization. The methods set forth in this book are not new; many have already proved successful in commercial and military endeavors and, perhaps, even within your own operation. Use of this manual will enable you to identify quality management techniques which you presently utilize and may also reveal areas of operation that could benefit from the application of additional quality management principles.

A properly designed and implemented quality management program for a power plant will provide cost benefits to all organizations involved. Borrowers will obtain cost benefits from the increased availability of their plants and fewer repair costs. Engineers will obtain cost benefits from less redesign time. Constructors and manufacturers will profit by reducing need for repairs, rework, and scrap. If a quality management program appears to lack cost effectiveness, the program selected may be too extensive, does not provide sufficient control to be effective, or is not working properly. This may also indicate that the cost benefits are not being adequately determined to provide a true picture of the program's cost effectiveness.

2. SCOPE

This manual is the third in a series of bulletins developed by the Rural Electrification Administration (REA) to assist borrowers in increasing the availability of their power plants. The other two bulletins are Bulletin No. 163-2, "Preventive Maintenance Management Manual" and Bulletin No. 163-3, "Operations Management Manual."

None of the three manuals is more important than the other. Each plays an important role during different phases of the plant's life. This bulletin, the Quality Management Manual, has the broadest scope and is applicable to all phases of the plant's life, from procurement and construction through operation. It is divided into the four major sections listed below.

Section I, in addition to providing a brief introduction and scope, offers some thoughts on how to instill a "quality attitude" among personnel and also outlines the economic advantages inherent in the quality management approach.

Section II of the manual provides guidance for establishing a quality management program. Guidelines for establishing responsibility, selecting equipment and systems to be included in the program, appraising existing practices, and improving present practices are included in this section.

Section III presents effective quality management practices which are useful for selecting and developing the appropriate quality management program. The section is divided into five subsections. The first one is a brief introduction; the remaining subsections deal with the various quality management practices applicable to the four phases of a power plant, that is, engineering and design, procurement, manufacturing, and construction.

Section IV provides information on measuring the effectiveness of the quality management program to assure that all participants are deriving cost-effective benefits from the implementation of such a program.

B. QUALITY APPROACH

1. A QUALITY ATTITUDE

It is widely assumed that the way to prevent power plant defects is to give workers extra money for doing good work. This solution for quality problems assumes that defects are primarily worker controllable; that is, the worker can prevent the majority of defects from occurring. It also assumes that workers have to be given extra pay to follow specification requirements. Both of these assumptions are weak. Most significant power plant defects are beyond the control of the workers.

It is also a fact that supervisors are given a number of conflicting goals. They are told to meet their schedule goals, they are told to keep safety in mind, they are told to meet their quality goals, and they are definitely told to meet their cost goals. Not only are they given many goals but the emphasis on these goals is constantly shifted by management as problem areas develop.

It is also true that attitudes are set from the top. This means that management's actions and not their words convey what is important. Management can talk all they want about quality, but if management's actions are focused only on meeting schedules and keeping costs down, the workers will aim for those goals. Consequently, quality goals will suffer.

It is obvious that a better solution for solving quality-related problems is for management to illustrate that they are serious about quality. Management can demonstrate this by establishing a quality management group. This new group, though it may consist of only one person, will give prominence to the quality function. With quality as its prime concern, the group can serve as a catalyst to stimulate quality awareness in all personnel and can help introduce quality planning into all areas of the organization.

The attainment of quality objectives is, and should always be, the responsibility of those who perform the work. This includes people such as the designer, welder, power plant operator, and purchasing agent. People are, in general, desirous of doing a job properly and will support management's efforts to involve them more in the planning and controlling phases of their jobs. The optimum organization includes an environment that effectively involves everyone in the quality of the product, respects workers, and permits them to be more fully involved.

During the performance of their work, personnel should perform interim examinations, checks, and inspections of their own work. However, verification that quality objectives have been met should be accomplished by persons who do not have direct responsibility for performing the work. It is important to recognize that these persons, whether they be design reviewers, checkers, test technicians, or inspectors, cannot improve the quality of the work. An inspector, for example, simply checks to determine whether the quality of a piping installation matches the designer's

specifications. If the inspector finds something wrong, the quality of the work is unsatisfactory. The inspector can only identify that poor quality work has been performed. The inspector cannot prevent it from occurring. When a large amount of poor work is identified, management will often blame the inspectors. "What are the inspectors doing? It's their job to make sure things go right." Shifting the responsibility to the inspector is wrong. It is management's job to make sure things go right. The inspector's job is to report whether management has succeeded.

2. THE ECONOMICS OF A QUALITY PROGRAM

Traditionally, quality management in the engineering, procurement, manufacture and construction of fossil fuel power plants has been largely informal, unrecorded, and unsystematic. However, as the consequences of a mistake become more and more expensive, there is an increasing need for predetermined and systematic quality programs.

More and more utility managers are becoming aware that effective quality programs are a prerequisite to good operations. They have found that quality programs, when applied only to the extent necessary, can make a significant contribution to their profitability and growth by minimizing deficiencies in a cost-effective manner.

Doing things right the first time adds nothing to the cost of a power plant. Doing things wrong is what costs money. Most of the delays and costs for rework, scrap, reinspection, and retest could be prevented by a properly managed quality function.

Quality problems can be separated into two categories: the "vital few" and the "trivial many." If you identify which are the "vital few" and concentrate on their solution, you can improve quality in a cost-effective manner.

By illustration, if there are 100 types of defects, you may find that perhaps 20 of these will account for approximately 80 percent of the costs. This means you can cut the economic losses, due to defects, in half by solving the problems that are caused by 10 to 15 types of defects instead of 100.

To evaluate the cost impact of power plant defects, the consequences of the defects must be determined. Some of the potential consequences are as follows:

a. Replacement or repair costs due to physical failure of the item or system;

b. Safety and legal aspects of the failure;

c. Effects on lowered availability and/or efficiency and subsequent loss of revenue.

While it is not economically feasible to eliminate all power plant defects, concentration on the "vital few" can pay dividends through defect prevention. The prevention methods utilized through design and engineering, procurement, manufacturing, and construction are the subject of this manual.

Although an effective quality management program will ultimately produce monetary savings, an initial "investment in quality" must be made. This funding of quality management program activities can be minimal since the program will typically change the way things are done in lieu of adding things to be done.

Management can effectively start by analyzing existing quality management activities. Existing methods which work should be maintained, cumbersome methods should be streamlined, and those which have limited value should be revised or discarded.

In each organization, there are many departments which perform functions important to quality and plant availability. Each department has an influence on the other's ability to achieve objectives economically and effectively. Inadequate communication and lack of standardization can produce deficiencies in the quality of the final product. A quality program can break down this communication barrier by highlighting interdepartmental relationships and illustrating how the work of one department affects another.

SECTION II

GUIDELINES FOR ESTABLISHING A QUALITY MANAGEMENT PROGRAM

A. COMMITTING TO THE ESTABLISHMENT OF A QUALITY MANAGEMENT PROGRAM

As discussed in the previous section, the objective of quality management is increased availability of REA-financed power plants by the cost-effective application of quality management techniques, such as those described in this manual. To achieve this objective, the borrower's top management should commit themselves to the establishment and implementation of a quality management program, make this commitment known to middle management and their present or prospective engineer, and evaluate the effectiveness of the program on a continuing basis.

B. ESTABLISHING RESPONSIBILITIES FOR A QUALITY MANAGEMENT PROGRAM

The borrower should retain the responsibility for establishing and executing a quality management program; however, the actual work of establishing a program for a new plant can be delegated to the engineer. This latter approach is in keeping with the responsibilities assigned to the engineer in REA Form 211, titled "Engineering Service Contract for the Design and Construction of a Generating Plant." This form delineates the responsibilities imposed on the engineer during the design, procurement, and construction of a power plant. Briefly, the engineer's efforts in these areas as per REA Form 211 include the following:

1. Design - preparing and submitting the project design manual, preliminary plans, detailed drawings and specifications;

2. Procurement - providing the form of the construction contract to be entered into between the contractor and the borrower; evaluating and recommending bidders for furnishing material, equipment, and services for the construction of the plant; providing all the necessary inputs for procuring the necessary or desirable permits, franchises, titles, rights, and authorizations;

3. Construction - supervising and inspecting all details of the construction of the plant in accordance with contractual requirements; maintaining a resident engineer at the plant site and sufficient staff to discharge the responsibility of the engineer; determining that the plant has been fully constructed in accordance with contractual requirements.

As shown in REA Form 211, the borrower places major responsibilities on the engineer for all aspects of design,

procurement and construction. The borrower and REA function in the approval capacity to oversee the engineer's work efforts. Since the quality management techniques are integrated into these efforts, the engineer should develop the quality management program for the power plant project.

The borrower should review and approve the engineer's program in the same fashion that the engineer's other work is approved. Depending on the size of the borrower's technical staff, the borrower may elect to monitor the engineer's implementation of the quality management program. This can be accomplished by a quality management engineer within the borrower's organization or by an outside consultant.

The engineer's responsibilities for establishing the quality management program for a power plant project typically include the following:

1. Determine which power plant structures, systems, and components have a significant effect on the availability of the plant and should therefore be engineered, manufactured, and constructed under a quality management program;

2. Establish a quality management program which covers the engineering and design, procurement and construction work performed directly by the Engineer;

3. Establish the quality management program requirements to be imposed upon vendors of systems and components which have a significant effect on the availability of the power plant and include these in the procurement specifications;

4. Establish the quality management program requirements to be imposed upon the construction contractor and include these in the construction contract. Identify to the constructor the structures, systems and components to which the constructor's quality management program is applicable;

5. Coordinate the quality management effort for multicontract construction to avoid schedule conflicts by means of long-range and daily planning.

C. SELECTING PLANT EQUIPMENT AND SYSTEMS TO BE INCLUDED IN A QUALITY MANAGEMENT PROGRAM

Determining which equipment and systems should be engineered, manufactured, and constructed under an upgraded quality management program requires the technical expertise of an

engineer who has intimate knowledge of the plant being designed as well as an awareness of plant performance problems within the industry.

The objective of the selection process is to determine which power plant structures, systems, equipment, and components warrant the special attention which will be provided when improved quality management practices are applied. (See paragraph IIE for guidance on improving quality management practices.)

It is obvious that due to cost considerations, not all equipment and systems should receive special attention. Those which should are the ones that significantly affect the availability of the power plant and also have a high failure rate. Based on their experience and concerns, borrowers should provide input regarding the selection of equipment and systems.

The methods engineers employ to accomplish this selection task vary from company to company just as design methods vary. Following is an example of a typical method which might be used.

(1) A list of power plant systems and equipment is prepared.

(2) Priority levels are assigned for systems and equipment based on the consequence of the failure of the item.

Four priority levels are listed below:

Level A - FAILURE CAUSES SHUTDOWN, SAFETY HAZARD, OR SIGNIFICANT ENVIRONMENTAL PROBLEMS

Level B - FAILURE CAUSES LOAD REDUCTION

Level C - FAILURE CAUSES REDUCED EFFICIENCY

Level D - OTHER

(3) Sources of failure and problem data compiled from plant operating experience and the power industry (such as NERC) are reviewed. The resulting data can be analyzed for the highest failure rates and the longest downtime over a significant time period.

(4) Problem systems and equipment revealed in (3) are compared with the priority levels assigned in (2). From this comparison, systems and equipment to be included in the improved quality management program are selected.

(5) The number of items included in the quality management program can be further reduced based on budgetary considerations and the ranking of systems and components within the highest priority level (level A).

D. APPRAISING EXISTING QUALITY MANAGEMENT PRACTICES

Before establishing a quality power plant management program, engineers should evaluate their existing quality management practices. Existing quality management practices are those actions being taken to provide the borrower with a power plant which will perform satisfactorily in service. The practices engineers employ to perform their engineering, design, procurement, and construction management work should be evaluated. In addition, requirements typically imposed on the constructors and vendors of equipment and systems important for plant availability should also be evaluated to identify which of these are quality management practices.

A questionnaire which engineers can use to appraise their present practices is provided herein. The questionnaire is divided into the following four areas: engineering and design, procurement, manufacturing, and construction. These four areas correspond to subsections B, C, D, and E of section III of this manual. The questionnaire includes most of the quality management techniques discussed in those subsections. Subsection paragraph numbers are identified at the end of each question to permit the user to clarify the intent of each question.

a. ENGINEERING AND DESIGN QUESTIONNAIRE

This portion of the questionnaire relates to the engineering and design activities of the engineer.

*Legend: Y = Yes
P = Partial
N = No

Questions	Answers*
1. Is design input, including borrower's input, clearly identified and documented? (See par. III B2 on Page No. 37)	Y-P-N
2. Is the design input reviewed and approved by the organization providing it? (See par. III B2 on Page No. 37)	Y-P-N
3. Are changes to the design input identified, documented, and approved by the same organization that prepared the original input? (See par. III B2 on Page No. 37)	Y-P-N
4. Are design analyses and calculations documented in sufficient detail to permit a technically qualified person to review them? (See par. III B3a on Page No. 38)	Y-P-N
5. Are methods for the preparation and control of specifications and drawings well defined? (See par. III B3b on Page No. 39)	Y-P-N
6. Is the preparation and control of other design documents well defined? (See par. III B3c on Page No. 40)	Y-P-N
7. Do written descriptions of the responsibilities of each organizational unit exist? (See par. III B4 on Page No. 40)	Y-P-N

Questions (cont'd)	Answers*
8. Are these organizational descriptions distributed to keep all parties advised of who is responsible for what? (See par. III B4 on Page No. 40)	Y-P-N
9. Are organizational changes rapidly reflected in revised descriptions? (See par. III B4 on Page No. 40)	Y-P-N
10. Are systematic methods for transmitting design information and changes between companies well defined? (See par. III B4 on Page No. 40)	Y-P-N
11. Are designs verified by competent individuals other than those who performed the original design? (See par. III B5 on Page No. 41)	Y-P-N
12. Are changes to designs also verified? (See par. III B5 on Page No. 41)	Y-P-N
13. Are documents controlled to assure that personnel are aware of and utilize proper and current documents? (See par. III B6 on Page No. 42)	Y-P-N
14. Are design changes processed in the same manner as the original design? (See par. III B7 on Page No. 43)	Y-P-N
15. When a deficiency is corrected, is the cause determined and appropriate changes made to prevent recurrence? (See par. III B8 on Page No. 44)	Y-P-N
16. Are deficiencies and corrective actions reported to appropriate levels of supervision and management? (See par. III B8 on Page No. 44)	Y-P-N
17. Are design records maintained and retrievable? (See par. III B9 on Page No. 44)	Y-P-N

Questions (cont'd)	Answers*
18. Are audits carried out to verify compliance with the requirements for performing all phases of the design process and are the results of these audits reviewed by management? (See par. III B10 on Page No. 45)	Y-P-N

b. PROCUREMENT QUESTIONNAIRE

This portion of the questionnaire relates to the engineer's procurement activities.

*Legend: Y = Yes
P = Partial
N = No

Questions	Answers*
1. Have the required contents of procurement documents been established and are preparers aware of these requirements? (See par. III C2a on Page No. 47)	Y-P-N
2. Are procurement documents reviewed to assure that they contain the necessary requirements? (See par. III C2b on Page No. 48)	Y-P-N
3. Are changes to procurement documents reviewed by the originating organization? (See par. III C2c on Page No. 49)	Y-P-N
4. Are bidders selected on the basis of an evaluation of their capability? (See par. III C3 on Page No. 49)	Y-P-N
5. Are bid packages evaluated to assure they conform to procurement documents? (See par. III C4 on Page No. 50)	Y-P-N
6. Are communications established between purchaser and supplier for coordination purposes? (See par. III C5a on Page No. 50)	Y-P-N
7. Are documents submitted by the supplier reviewed to evaluate performance? (See par. III C5b on Page No. 51)	Y-P-N
8. Is the acceptability of items and services furnished by suppliers verified? (See par. III C6 on Page No. 51)	Y-P-N

Questions (cont'd)	Answers*
9. Are one or more of the acceptance methods below used?	Y-P-N
a) Certificate of conformance	
b) Receiving inspection	
c) Surveillance	
d) Installation verification testing (See par. III C6 on Page No. 51)	
10. Are there methods for the supplier to inform the purchaser of non-conformances? (See par. III C7a on Page No. 55)	Y-P-N
11. Are the suppliers' corrective action on nonconformances verified by the purchaser? (See par. III C7b on Page No. 56)	Y-P-N
12. Are the records which are generated during the procurement cycle maintained? (See par. III C8 on Page No. 56)	Y-P-N
13. Are audits performed to verify compliance with the requirements for performing all phases of the procurement process and are the results of these audits reviewed by management? (See par. III C9 on Page No. 57)	Y-P-N

c. MANUFACTURING QUESTIONNAIRE

This portion of the questionnaire relates to the requirements the engineer typically imposes on manufacturers of important equipment.

*Legend: Y = Yes
P = Partial
N = No

Questions	Answers*
Do procurement documents require manufacturers to do the following:	
1. Define manufacturing activities in written work procedures? (See par. III D3 on Page No. 59)	Y-P-N
2. Control the issuance of work procedures, drawings, and other documents affecting quality to preclude the possibility of use of outdated or inappropriate documents? (See par. III D4 on Page No. 60)	Y-P-N
3. Require the group which originally reviewed and approved a document to review and approve changes to it? (See par. III D4 on Page No. 60)	Y-P-N
4. Employ material identification and control methods to prevent the use of incorrect or defective materials and parts? (See par. III D5 on Page No. 61)	Y-P-N
5. Certify persons who perform special processes such as welding, heat treating, etc. to perform this work? (See par. III D6b on Page No. 62)	Y-P-N
6. Define special process methods in detailed procedures? (See par. III D6c on Page No. 62)	Y-P-N
7. Plan inspections and define them in written inspection plans? (See par. III D7a on Page No. 62)	Y-P-N

Questions (cont'd)	Answers*
8. Perform receiving inspection on materials and equipment inspected upon receipt from the supplier? (See par. III D7b on Page No. 63)	Y-P-N
9. Perform in-process inspections for each work operation where necessary to assure quality? (See par. III D7c on Page No. 63)	Y-P-N
10. Perform final inspections on completed systems or items to verify conformance with requirements? (See par. III D7d on Page No. 63)	Y-P-N
11. Monitor process methods, equipment, and personnel to obtain assurance of quality when the inspection of processed items is impossible or disadvantageous? (See par. III D7f on Page No. 64)	Y-P-N
12. Perform inspections with personnel who are not responsible for the performance of the work being inspected? (See par. III D7i on Page No. 65)	Y-P-N
13. Document inspection results? (See par. III D7j on Page No. 65)	Y-P-N
14. Monitor inspection result data to determine which manufacturing processes are producing deficiencies? (See par. III D7k on Page No. 65)	Y-P-N
15. Plan tests and define tests in detailed test procedures? (See par. III D8b on Page No. 66)	Y-P-N
16. Maintain status information for the required inspections and tests? (See par. III D9 on Page No. 67)	Y-P-N
17. Calibrate equipment and instruments which are used to measure and test items and systems? (See par. III D10 on Page No. 68)	Y-P-N

Questions (cont'd)	Answers*
18. Give adequate attention to the handling, storage, and cleaning of items and systems? (See par. III D11 on Page No. 69)	Y-P-N
19. Control nonconforming items to prevent their inadvertent use? (See par. III D12 on Page No. 70)	Y-P-N
20. Carry out audits to verify compliance with the requirements for performing all phases of the manufacturing process and require that the results of these audits are reviewed by management? (See par. III D14 on Page No. 71)	Y-P-N

d. CONSTRUCTION QUESTIONNAIRE

This portion of the questionnaire relates to the engineer's supervision and inspection of construction activities, and to the requirements the engineer typically imposes on constructors.

*Legend: Y = Yes
P = Partial
N = No

Questions	Answers*
Part I	
Does the engineer's construction inspection system include the following:	
1. Are inspections planned and defined in written inspection plans? (See par. III E7a on Page No. 80)	Y-P-N
2. Do materials and equipment undergo receiving inspection upon receipt from the supplier? (See par. III E7b on Page No. 80)	Y-P-N
3. Are in-process inspections performed for each work operation where necessary to assure quality? (See par. III E7c on Page No. 81)	Y-P-N
4. Are final inspections performed on completed systems or items to verify conformance with requirements? (See par. III E7d on Page No. 82)	Y-P-N
5. Where the inspection of processed items is impossible or disadvantageous are process methods, equipment, and personnel monitored to obtain assurance of quality (See par. III E7e on Page No. 82)	Y-P-N
6. Are inspection results documented? (See par. III E7i on Page No. 84)	Y-P-N
7. Are inspection results monitored to determine which construction processes are producing deficiencies? (See par. III E7j on Page No. 85)	Y-P-N

Questions (cont'd)	Answers*
8. Are tests planned and defined for the engineer's test personnel in detailed test procedures? (See par. III E8b on Page No. 86)	Y-P-N
9. Is status information maintained for required inspections and tests? (See par. III E9 on Page No. 87)	Y-P-N
10. Are the equipment and instruments the engineer uses to measure and test items and systems calibrated? (See par. III E10 on Page No. 88)	Y-P-N
11. Are nonconformances found by the engineer controlled to assure that they are resolved? (See par. III E12 on Page No. 91)	Y-P-N
12. Are audits carried out to verify compliance with the requirements for inspecting all phases of the construction process and are the results of these audits reviewed by management? (See par. III E14 on Page No. 92)	Y-P-N

Questions	Answers*

Part II

Do procurement documents for construction work require constructors to do the following:

1. Define construction activities in written work procedures? Y-P-N
   (See par. III E3 on Page No. 75)

2. Control the issuance of work procedures, drawings, and other documents affecting quality to preclude the possibility of use of outdated or inappropriate documents? Y-P-N
   (See par. III E4 on Page No. 77)

3. Require the group which originally reviewed and approved a document to review and approve changes to it? Y-P-N
   (See par. III E4 on Page No. 77)

4. Employ material identification and control methods to prevent the use of incorrect or defective materials and parts? Y-P-N
   (See par. III E5 on Page No. 78)

5. Certify persons who perform special processes such as welding, heat treating, etc. to perform this work? Y-P-N
   (See par. III E6b on Page No. 79)

6. Define special process methods in detailed procedures? Y-P-N
   (See par. III E6c on Page No. 79)

7. Plan inspections and define them in written inspection plans? Y-P-N
   (See par. III E7a on Page No. 80)

8. Perform receiving inspection on materials and equipment upon receipt from the supplier? Y-P-N
   (See par. III E7b on Page No. 80)

Questions (cont'd)	Answers*
9. Perform in-process inspections for each work operation where necessary to assure quality? (See par. III E7c on Page No. 81)	Y-P-N
10. Perform final inspections on completed systems or items to verify conformance with requirements? (See par. III E7d on Page No. 82)	Y-P-N
11. Monitor process methods, equipment, and personnel to obtain assurance of quality when the inspection of processed items is impossible or disadvantageous? (See par. III E7e on Page No. 82)	Y-P-N
12. Perform inspections with personnel who are not responsible for the performance of the work being inspected? (See par. III E7h on Page No. 83)	Y-P-N
13. Document inspection results? (See par. III E7i on Page No. 84)	Y-P-N
14. Monitor inspection result data to determine which construction processes are producing deficiencies? (See par. III E7j on Page No. 85)	Y-P-N
15. Plan tests and define tests in detailed test procedures? (See par. III E8b on Page No. 86)	Y-P-N
16. Maintain status information for the required inspections and tests? (See par. III E9 on Page No. 87)	Y-P-N
17. Calibrate equipment and instruments which are used to measure and test items and systems? (See par. III E10 on Page No. 88)	Y-P-N
18. Give adequate attention to the handling, storage, and cleaning of items and systems? (See par. III E11 on Page No. 90)	Y-P-N

Questions (cont'd)	Answers*
19. Control nonconforming items to prevent their inadvertent use? (See par. III E12 on Page No. 91)	Y-P-N
20. Carry out audits to verify compliance with the requirements for performing all phases of the construction process and require that the results of these audits be reviewed by management? (See par. III E14 on Page No. 92)	Y-P-N

E. IMPROVING QUALITY MANAGEMENT PRACTICES

1. Deciding If Improvements Are Needed

a. Evaluating Existing Practices

After completion of the questionnaire, the engineer and the borrower should review the results of the appraisal. Questions which received "Partial" or "No" answers should be discussed to decide if it would be beneficial and cost-effective to upgrade those work areas.

Following is a sample of items which would be discussed:

(1) Previous problems in the area;

(2) The potential for defects in the area;

(3) The potential consequences of defects in the area;

(4) The costs of improving the area versus the costs of potential defects.

The appropriate quality management program for a particular power plant project should be selected by considering the success of present methods.

During the above discussions, reference to section III of this manual would be useful. It contains information on effective quality management practices which can be used for guidance in making these decisions.

b. A Two-Level Quality Management Program

Frequently, it is not cost-effective to upgrade all work performed. The potential consequences of defects are dependent upon the equipment or systems that are defective. Because of this, it may be advisable to establish a two-level quality management program. Level one of the program would consist of the existing quality management practices; level two would be applicable to the plant equipment and systems designated as critical to plant availability. This higher level program would include the existing practices and the upgraded, or improved, practices resulting from the above discussions. By this method, work performed

in accordance with the higher level program would receive "special attention."

Although the establishment of programs with three or four levels would appear to be cost-effective, this is not advisable. These types of programs cause confusion because of the many variables inherent in the numerous levels.

c. Imposing Requirements on Vendors and Constructors

Vendors and constructors are contractually obligated to manufacture or construct equipment or systems which satisfy the quality requirements of the specifications. The quality management practices they employ, however, have a great effect on the quality their product and ultimately on the availability of the plant.

The imposition of quality management requirements on vendors and constructors, and verification of their implementation, will provide greater confidence that the quality stipulated in the engineer's specification will be met. Choosing a more comprehensive quality management program than necessary may, however, lead to higher costs without sufficient benefits.

2. Developing an Action Plan

Once the areas requiring improvements are determined, steps to accomplish these improvements should be established, using existing procedures, wherever possible. These steps should be documented in an action plan. In addition, the action plan may allocate funding, establish target dates, identify personnel responsible for implementation, and provide for status information. This plan may be published monthly for management's review and assessment.

3. Implementing the Action Plan

In order to implement the action plan, it may be desirable to first select a full-time quality management coordinator. The role of quality management coordinator should be given to an individual who is motivated, diplomatic, has displayed leadership qualities and a positive attitude, and possesses an appreciation of costs. The coordinator should be given sufficient organizational authority to identify quality management problems, recommend solutions, verify implementation,

and have direct access to top management. The coordinator would be responsible for all aspects of the implementation program, including the following:

(a) Selecting the necessary in-house personnel, on an as-needed basis, to modify existing procedures or develop new procedures which describe how to implement the desired improvements.

(b) Directing personnel to assure work that is progressing satisfactorily within budget and schedule.

The size of the quality management coordination staff may be one or more individuals on an as-needed basis. Individuals selected for the staff should have the appropriate expertise necessary for the particular task to be performed.

If the required expertise is not available, indoctrination and training programs may be established to assure that personnel implementing the program will have adequate knowledge. This indoctrination and training should be an extension of their formal education or work experience. In lieu of training in-house personnel, the necessary expertise may be obtained through an outside consultant.

To assure that the role of the quality management staff within the organization is completely understood, a management policy statement should be promulgated. This statement would discuss the function of the quality management staff and its involvement in the achievement of the organization's quality objectives. Organizational charts and functional descriptions would further clarify the role of the quality management staff.

4. Preparing the Implementing Procedures

Written procedures describing implementation of the improvement program should be prepared. The applicable sections of this manual can be used for guidance. Additional guidance and detail in the preparation of implementing procedures may be gathered from quality assurance texts such as those given in the bibliography of this manual.

In the preparation of procedures, the assistance of those who are, and will be, involved in an activity is extremely important. Agreement, approval, and support

at the management level are essential. The involvement of all managers in the preparation of the procedures greatly facilitates final agreement and, ultimately, their implementation. Prior to issue, the procedures should be reviewed and approved by management to provide the authority necessary for their implementation.

Each procedure should be written in a simple, clear, and concise manner and should address the following:

(a) Purpose - explain the purpose and scope of the procedure;

(b) Applicability - state to whom this procedure applies;

(c) Responsibility - state who is responsible to do what;

(d) Details of the procedure - state, in a sequential manner, what is to be done, how it is to be done, a means of verifying that it was done, and a means of correcting any deficiencies found;

(e) Attachments and exhibits - include sample forms, tables, and charts to serve as a visual understanding of the procedure and as a suggested way to record data.

In the event the implementing procedures are modified, they should be controlled to assure that the latest issue is distributed to personnel involved in the activity.

5. Monitoring the Implementation of New Procedures

Once the implementation procedures are completed, they should be phased into their respective areas in accordance with a schedule to ensure a smooth transition. Translating the procedures into smoothly running operations requires time. People must become accustomed to different ways of operating.

As they are implemented, the procedures should be evaluated. These evaluations may indicate that procedural changes or training of personnel implementing the procedures is required. Adjustments to the procedures may occur as many times as evaluations occur, and this may be a continuous process until implementation is completed.

Meetings may be periodically convened to allow management to review how effectively the new procedures are meeting the organization's objectives.

Section III

EFFECTIVE QUALITY MANAGEMENT PRACTICES

A. INTRODUCTION

The quality management practices presented in section III are for information and guidance. These practices are applicable to the engineering and design, procurement, manufacturing and construction phases of a power plant. At the borrower's discretion, any or all of these techniques may be used to develop quality management programs appropriate for the needs of the particular project. The programs selected may be used for the construction of new power plants and/or the retrofit activities of existing plants using the pertinent sections applicable to the activity to be performed.

It would be unrealistic to assume that there is even one borrower in the country who is presently in the position to implement all the quality management techniques presented in this section. Some borrowers may never have a justifiable need for some of the control methods presented. The fact remains, however, that the principles and techniques included in this manual have proved effective in producing a better product by every industry using them.

Borrowers must carefully evaluate the need for and the extent of control desired. The ability to justify the need for quality measures is dependent upon a full understanding of the practices presented in this section and an intelligent application of them.

B. ENGINEERING AND DESIGN PRACTICES

1. GENERAL

This section discusses the quality management practices applicable to the engineering and design activities of the engineer.

To assure a satisfactory design, a good quality management program begins with the assignment of a sufficient number of competent, properly supervised personnel to the design effort. Good engineering and design practices and procedures are established at the start and their implementation is systematically verified.

Properly implemented quality management practices can minimize deficiencies in a cost-effective manner provided that these practices are applied only to the extent necessary. Care must be taken to develop and implement a quality management program which aids design and construction productivity.

Deficiencies in the drawings, specifications, and other engineering and design documents can adversely affect cost and schedule. Design deficiencies can range from straightforward errors which can be detected in the review process by other engineers and supervisors to subtle ones arising from complex interfaces between engineering disciplines and with vendors and the constructors.

REA Form 211, "Engineering Service Contract For The Design And Construction Of A Generating Plant," delineates the responsibilities imposed on the engineer. Among these responsibilities are quality practices which ensure that good engineering and design practices will be followed. Quality management techniques that will reduce design deficiencies are discussed in the following design activities:

(a) Design Criteria

(b) Design Process

(c) Design Interfaces

(d) Design Verification

(e) Document Control

(f) Design Change Control

(g) Corrective Action

(h) Records

(i) Audits

2. DESIGN CRITERIA

Design criteria are used to establish the assumptions and philosophies under which engineering and design are performed. Criteria may include site related and performance data, local licensing and regulatory statutes, and other constraints imposed by the borrower. As an example, REA Form 211 requires that design criteria be incorporated in a project design manual. Design criteria should be clearly identified and documented. The document should be prepared and reviewed by the engineer and approved by the borrower and REA. Similarly, any changes made to the specified design criteria should be identified, documented with reasons for the changes, and approved by the same organizations that approved the original document.

The project design manual is not intended to provide all the detailed requirements to be incorporated into final design documents. Rather, its intent is to provide the basis and constraints under which engineering and design are performed.

3. DESIGN PROCESS

The design process is the method for translating design criteria into design documents. Design documents include drawings and specifications, procedures, etc. To help prevent deficiencies, it is important that the sequence of activities for preparing these documents be well defined. These activies include preparation, review, approval, and distribution of design documents. Written procedures are useful in controlling these activities.

a. Design Analyses

Design analyses and calculations are used for establishing detailed engineering and design features, the results of which will be incorporated into specifications, drawings and other design documents.

A typical procedure for the preparation of analyses and calculations should include provisions for the documentation of the following:

1) Identification of the document by project, subject, number, etc., to permit ready reference, indexing, filing, and retrieval;

2) Identification of originator, date, and revision;

3) Statements of objective or purpose;

4) Record of the design inputs utilized and their sources;

5) Inclusion of references;

6) Documentation of the assumptions and identification of those assumptions that require verification as the design proceeds;

7) Methods and physical units (pounds, feet, etc.) used;

8) Identification of computer calculations including inputs, outputs, computer program, and documentation that the adequacy of the computer program has been verified;

9) Spaces for the reviewers' and approvers' signatures and date.

By incorporating the above information in the completed analyses and calculations, they will contain the detail required to permit a technically qualified person to independently verify the adequacy of the results. These independent reviews and verifications of design analyses and calculations improve the quality of the initial design and help avoid deficiencies in specifications and designs.

b. Specifications and Drawings

Specifications and drawings are prepared to define the design. They contain technical requirements necessary for the procurement of materials, equipment, systems, and services for the construction of a plant. The correct and complete definition of a design is as important as the design itself. Specifications and drawings must be definitive--not just capable of being understood, but so clear that they cannot be misunderstood. Sufficient detail is required to assure that the design's intent is carried out. Legibility and proper reproduction are also important to avoid misinterpretations.

A thorough, independent review of specifications and drawings will help verify that they will accomplish their purpose.

Typical procedures for the preparation and control of specifications and drawings include the following:

1) Document format requirements, including drafting standards and symbols used for drawings;

2) Document identification system, including indexes;

3) Indication of status;

4) Drawing checking methods;

5) Review and approval requirements;

6) Issuance and distribution;

7) Revision methods;

8) Storage and control originals or master copies.

c. Other Design Documents

Engineering and design personnel often convey other design information, such as installation instructions and test procedures. This information is prepared and controlled via the same procedures used for specifications and drawings.

4. DESIGN INTERFACES

Each organization assigns resposibilities for design activities to various departments or groups. Responsibilities may also be assigned to subcontractors. As organizations increase in size, deficiencies may occur because responsiblities are not sufficiently defined. The preparation of written descriptions of each organizational unit's responsibilities will uncover these poorly defined areas. Sometimes, it is also helpful to present the responsibilities in pictorial form through the use of a matrix or flow chart. Often, these visual depictions provide a more understandable representation of the overall picture.

The distribution of these completed descriptions and charts will keep all parties advised of who is responsible for what. Since organizations change, it is important to remember that revisions are as essential as the initial issue of these descriptions.

A complete description includes responsibilities for the preparation, review, approval, and revision of documents involving the design interface. Equally important is the inclusion of systematic methods for transmitting design information and changes across the design interfaces.

The above applies to both internal and external interfaces. For external interfaces, the identity of key personnel in external communication channels is important. In addition to their names and titles, their responsibilities for decisionmaking, resolving problems, and providing and reviewing information are important.

5. DESIGN VERIFICATION

Design verification is basically a checking process. Its purpose is to confirm the adequacy of a completed or revised design. The extent of verification is dependent upon the importance of the item to plant availability, the complexity of the design, the degree of standardization, the state of the art, and the similarity with previously proven designs.

Various methods may be used. These methods vary from spot checking of calculations to actual testing of the design in the field. The verifications should be performed by individuals or groups other than those who performed the original design.

Where changes to previously verified designs are made, design verification is performed for the areas changed, including an evaluation of the effects of those changes on the overall design.

The various methods of design verification are discussed below:

a. Design Reviews

Design reviews are performed to provide assurance that drawings, specifications and analyses are correct and satisfactory. These reviews can range from limited checks of such things as the design approach and results obtained to detailed checks of the completed design. The results of reviews are documented to ensure that all involved parties are aware of the results and that the findings are implemented. Design reviews address the following typical questions:

1) Are inputs correctly selected and incorporated into design?

2) Are design assumptions adequately described and reasonable?

3) Are applicable codes and standards properly identified and are their requirements included in the design?

4) Do the design documents contain sufficient acceptance criteria to permit verification of the correctness of the design?

b. Alternate Calculations

Verification of some types of calculations or analyses may be achieved by comparison with alternate methods of calculation or analyses. The alternate method used may be a more simplified approach. Although the simplified method may not exactly check the original calculation, it should still provide results consistent with original calculation or analyses.

c. Testing

Design verification for a design or a specific design feature can be achieved by suitable testing of a prototype or initial production unit. Testing should demonstrate adequacy of performance under the most adverse design conditions.

If testing indicates that modifications to an item are necessary to obtain acceptable performance, the modifications are documented and the item is modified and retested.

6. DOCUMENT CONTROL

It is important that engineering and design personnel are aware of and utilize proper and current documents. This applies to procedures which define the duties of the engineer's design personnel, to design input documents, and to interfacing specifications and drawings used by personnel during their engineering and design work.

It is equally important that engineering and design groups transmit proper and current design output documents, such as specifications and drawings, to internal and external groups which utilize these documents. Methods for accomplishing this include the following:

a. Document receiving systems which record what has been received and recall obsolete revisions from users;

b. Indexes of design input documents with revisions recorded therein;

c. The periodic issuance of drawing and specification lists to permit users to check the currency of their copies;

d. Acknowledgement of receipt systems wherein the recipient informs the sender that the documents have been received;

e. Distribution lists which are updated and kept current to assure that the proper personnel are sent all the required documents necessary to perform the work.

7. DESIGN CHANGE CONTROL

The quality of a design can be degraded by improper design changes. If changes are subjected to control measures commensurate with those applied to the original design, errors of this type can be reduced.

Design changes may be initiated as a result of the following:

a. Review of engineering and design documents;

b. Discovery of a deficiency or error;

c. Changes in codes and standards;

d. Borrower, REA, or contractor requests;

e. Physical interference, or functional or performance deficiencies discovered during construction or operation.

Change requests made during engineering, design, procurement, fabrication, and construction of a plant require the review and approval of the same personnel or organization that performed the original design. Change requests made during the operational phase of a plant require the review and approval of competent technical personnel who are authorized to approve changes. If approved changes are distributed in a timely and controlled manner, the use of superseded design documents will be minimized.

Minor changes to design documents, such as inconsequential editorial corrections and changes, would not necessarily need to go through a complete review and approval cycle. If these types of exceptions are clearly defined, then personnel will know that all other types of changes are to undergo complete review and approval.

8. CORRECTIVE ACTION

Corrective action includes correcting a deficiency, determining the cause (especially of recurring deficiencies) and instituting the appropriate changes in the design process to help prevent recurrence. Deficiencies in the design may be detected in the following ways:

a. Design verification measures

b. Personnel using the design documents

c. Audits

d. Tests

e. Actual failure

Deficiencies and corrective action should be reported to appropriate levels of supervision and management to assure corrections are made. Until corrective action has been accomplished, the identified deficiency cannot be expected to vanish. The deficiency is not closed until corrective action has been completed, and the action has been determined to have been effective. For most deficiencies then, there are two distinct phases of follow-up. The first is verification that the corrective action was implemented on schedule. The second is an assessment of the degree to which the corrective action eliminated the deficiency found. By identifying the personnel responsible for the proposed corrective action, management can better monitor progress of the required action and direct coordinated efforts or intercede, where necessary, to assure timely completion.

9. RECORDS

Design records document the design and provide evidence that the design and design verification processes were satisfactorily performed. Design records include not only the final design documentation such as drawings, specifications, and revisions thereto, but also include other important information, such as the sources of the design inputs which support the final design.

Design records should be maintained and should be legible, identifiable, and retrievable. The orderly retention of records will permit a reevaluation of the

design and the design methods employed if equipment or system problems are encountered. Since records also indicate if required design control measures were followed, they also are needed to perform audits of design activities.

10. AUDITS

The engineer and/or borrower should perform audits to verify compliance with the quality management program and to measure the effectiveness of the program during all phases of the design process. Typically, the essential steps of the audit are as follows:

a. Planning the audit by means of a planning document which defines the organizations and activities to be audited and the frequency of the audits;

b. Providing audit personnel who are familiar with the types of activities to be audited and who do not have direct responsibilities in the areas being audited;

c. Performing the audit in accordance with guidelines which identify those activities which affect quality;

d. Preparing the audit report which summarizes the audit results and details the nonconformances observed;

e. Submitting the audit report to management responsible for the area audited for review and corrective action for the nonconformances;

f. Re-auditing of nonconforming areas when it is considered necessary to verify implementation of the required corrective action.

See section IV for further discussion of the above steps.

C. PROCUREMENT PRACTICES

1. GENERAL

This section provides guidelines for the control of activities performed during the procurement of power plant equipment, materials, and services. Virtually all organizations involved in power plant projects engage in procurement activities. The methods presented in this section are primarily for the engineer; however, these methods can be useful to others such as borrowers, constructors, and manufacturers.

It is important to remember that an organization can be either a purchaser or a supplier. For a given power plant procurement, however, the organization is one or the other. For example, although the constructor is a supplier of construction services to the borrower, it functions as a purchaser when procuring construction materials.

The procurement controls presented in this section can reduce defects which may occur during the procurement process due to the many organizations and activities involved. Consequently, these controls provide greater assurance that the purchaser will obtain satisfactory items or services used in power plants from suppliers.

The procurement process activities discussed in this section are as follows:

a. Preparation of Procurement Documents

b. Selection of Bidders

c. Bid Evaluation and Award

d. Purchaser/Supplier Communications

e. Purchaser's Acceptance of Items or Services

f. Control of Nonconformances and Corrective Action

g. Records

h. Audits

2. PREPARATION OF PROCUREMENT DOCUMENTS

There are many instances of incomplete, erroneous, or misunderstood procurement documents for power plant equipment or services. Unfortunately, many of these defects are not found early enough to avoid costly schedule delays. To assure that the supplier fully understands the contractual commitments in furnishing an item or service for a power plant, it is important that the purchaser's procurement document specifies or references accurately, clearly, completely, and concisely all the applicable requirements which are necessary to assure adequate quality of items or services.

a. Procurement Document Contents

Procurement documents prepared by the engineer include contract forms (e.g., REA Forms 198, 200, etc.), administrative instructions, and other items. In addition, the procurement documents prepared by the engineer and other purchasers should include the following information, as found necessary by the purchaser.

1) Scope of Work - A clear statement or listing of the scope of work to be performed by the supplier.

2) Technical Requirements - A technical description of the items or services to be furnished. This may be done by reference to specific drawings, specifications, codes and standards, or other documents. Test, inspection, and acceptance requirements should be included, as well as special instructions for cleaning and packaging.

3) Quality Management Program Requirements - A description of the quality assurance program requirements that the purchaser feels are necessary to impose on the supplier. Requirements which the supplier is to impose on subcontractors when purchasing items or services would also be included here.

4) Right of Access - Provisions for the purchaser's access to the supplier's facilities and records for the purpose of inspecting, auditing, and expediting the

suppliers' manufacturing activities. The purchaser's inspection or auditing of the supplier's activities may permit the discovery of defects early in the manufacturing cycle. This helps to reduce construction delays due to discovery of faulty materials and equipment during the construction cycle. Also, include provisions for similar access to the supplier's subcontractors if quality management program requirements are imposed on the subcontractors.

5) Documentation - Identification of documentation which the supplier is required to submit to the purchaser for information or review and approval.

6) Nonconformances - Methods for the supplier to report nonconformances to the purchaser. Also, methods for the supplier to obtain the purchaser's approval of the disposition of the nonconformances.

b. Procurement Document Review

The completed procurement documents should be reviewed by the purchasing organization for completeness and to assure that they contain the appropriate information specified in paragraph 2a above. These reviews should be performed prior to releasing the procurement documents for bid. These reviews should be performed by personnel who have access to pertinent information and who have an adequate understanding of the requirements and intent of the procurement documents. To provide verification that the review was performed, it is necessary to document the review.

Changes to the requirements contained in procurement documents which are agreed to as a result of the bid evaluation or precontract negotiations, where permitted by the applicable bidding procedure, should be reviewed and incorporated into the procurement documents prior to contract award. This review should include the following:

1) Analysis of exceptions or changes requested or specified by the supplier and determination of the effects such changes may have on the intent of the procured items

2) Determination of any additional or modified design input imposed after preparation of the procurement documents.

c. Procurement Document Changes

Changes to issued procurement documents because of modification or clarification of requirements should be processed in the same manner and by the same organization as the original issue of the document. This would reduce defects because there would be less chance of something being overlooked by less knowledgeable personnel.

3. SELECTION OF BIDDERS

a. Evaluation and Selection of Bidders

Qualified suppliers are essential to obtain reliable items and services on schedule. Therefore, the selection of bidders should be based on an evaluation of their capability to provide power plant items or services which satisfies the requirements of the procurement documents. Some of the evaluation methods used to select qualified suppliers are as follows:

1) Evaluation of the prospective bidder's history of providing identical or similar items which have performed satisfactorily in actual use. The information evaluated may be from the purchaser's own experience with the prospective bidder's products or information obtained directly from other customers. This review should include the evaluation of commercial, technical, and schedule compliance history.

2) Evaluation of the prospective bidder's technical and quality capabilities for furnishing a satisfactory product. The evaluation may take the form of a survey of the prospective bidder's facilities, personnel, operations, and the implementation of its quality management program. In lieu of a survey, the purchaser may review information provided by the prospective bidder on its capabilities, which can be objectively evaluated. Once the evaluation is completed and prospective suppliers are selected for

bidding on power plant items and services, they are known as being prequalified.

4. BID EVALUATION AND AWARD

The evaluation of bids to assure that they conform to the procurement document requirements is an important step in purchasing a quality power plant product. The bid should be evaluated by the purchaser for the following quality related subjects, as applicable to the type of procurement:

1) Technical considerations

2) Exceptions taken

3) Alternate recommendations

The above evaluation of the bidder's conformance to the procurement document is then factored in with other considerations, such as warranties, schedules, price, price adjustments, and terms and conditions for the final bid evaluation, subject to the requirements of the applicable bidding procedure (e.g., REA Bulletin 40-6).

Prior to the award of the contract, the purchaser should ensure that any outstanding questions regarding the bidder or the bid have been resolved satisfactorily.

5. PURCHASER/SUPPLIER COMMUNICATIONS

a. Planning and Coordination

The purchaser should initiate pre- and post-award communications with the supplier. The depth and form of these communications depend on the uniqueness, complexity, and frequency of procurement with the same supplier, and past supplier performance for the specific items or services covered by the procurement document.

The communications may take the form of meetings, telephone calls, or written correspondence. Their purpose is to establish that the supplier understands the procurement requirements; convey the purchaser's intentions for monitoring and evaluating the supplier's performance; and review the planning and manufacturing techniques, tests, inspections, and processes to be employed by the supplier to meet the procurement requirements.

When purchaser notification points, such as hold and witness points, are deemed necessary, they should be identified at this time. These communication activities should be established early in the procurement process to assure effective coordination.

b. Control and Review of Supplier Generated Documents

One method of evaluating a supplier's performance is to review documents, such as drawings, procedures, inspection and test reports, and other documents that are generated during the procurement process. If the documents generated are not acceptable, they should be quickly corrected and approved to prevent delays in the procurement process. Therefore, it would be advantageous to establish a method for controlling the processing of documents to obtain their approval in an expeditious manner.

6. PURCHASER'S ACCEPTANCE OF ITEMS OR SERVICES

Reliance soley on well-defined procurement documents, cautious selection of bidders,and careful evaluation of bids to obtain satisfactory items or services from a supplier may not assure a quality product. The purchaser also needs to verify that the items or services being furnished by a supplier are acceptable, that is, comply with the procurement document requirements.

There are a number of methods which can be used to determine their acceptability. Some of these methods are supplier certification of conformance, receiving inspection, surveillance, post-installation testing, or combinations of these.

a. Certificate of Conformance Method

In certain cases where there is no direct inspection by the purchaser, the purchaser may accept an item based on a supplier's certificate of conformance. A certificate of this type states that the specified requirements have been met. This certificate would be in addition to specific documentation, such as material certificates or reports of tests performed which may be required by procurement documents. Even though the supplier is obligated to furnish acceptable items in accordance with contract requirements, the certificate of

conformance would further motivate the supplier to furnish an acceptable item.

The certificate should identify the following:

1) The item or service;

2) The acceptance requirements and a statement that the items or service conforms to these requirements;

3) The responsible person attesting to the authenticity of the certificate and that person's signature.

Acceptance by this method is usually satisfactory when the item or service is of a simple design and involves standard materials, processes, and tests. This method may be used for nuts, bolts, flanges, pipe, gages, thermometers, etc.

b. Receiving Inspection Method

The purchaser may accept an item or service solely by receiving inspection when the completed items or services are as follows:

1) Relatively simple or standard in design, manufacture, and test;

2) Adaptable to standard receiving inspections and/or tests to verify quality characteristics;

3) Not adversely affected in integrity, function, or cleanliness during receiving inspection operations.

Receiving inspections should be specified in written instructions which state those features to be inspected. The features include identification; dimensional, physical, and other characteristics; freedom from shipping damage; and cleanliness. Some examples of types of power plant equipment for which receiving inspection might be desired are electrical cable, cement, aggregate, fire protection equipment, structural steel, rebar, standard pumps and electric motors.

c. Surveillance Method

The surveillance method is the monitoring, witnessing, or observing of supplier activities at their facilities to obtain assurance that the item or service meets procurement document requirements.

Acceptance by the surveillance method may be most desirable when the item or service:

1) Is vital to plant reliability;

2) Has quality characteristics that are difficult to verify after delivery to the purchaser's facilities;

3) Is complex in design, manufacture, and test.

The surveillance method may not be warranted when the quality of the item can be verified by review of tests reports, inspections upon receipt, or other means.

When the surveillance method is used, it should be performed at intervals consistent with the importance and complexity of the item or service.

The surveillance method activities may include checking that the following has been accomplished:

1) Documentation on materials, inspections, and tests have been approved;

2) Fabrication procedures and processes have been complied with and that the applicable qualifications, process records, and certifications are available;

3) Components and assemblies have been inspected, examined, and tested as required and applicable inspection, test, and certification records are available;

4) Nonconformances have been corrected as required;

5) Components and assemblies are cleaned, preserved, packed, and identified in accordance with specified requirements.

Some examples of types of power plant equipment for which the surveillance method might be desired are selected boiler components (e.g., water walls, steam drum, economizer), boiler feed pumps, switchgear, large motors, motor control centers, main transformer, coal and ash handling systems, crushers, precipitator, demineralizer, and circuit breakers.

d. Installation Verification Testing at the Power Plant Site.

Installation verification tests are tests which verify the satisfactory performance of completed systems, sub-systems and their components. Functional, preoperational, and operational tests fall in this category.

Acceptance by this method may be most advantageous under the following conditions:

1) It is difficult to verify the quality characteristics of the item without it being installed and in use;

2) The item requires an integrated system checkout or test with other items to verify its quality characteristics;

3) The item cannot demonstrate its ability to perform its intended function except when in use.

Some examples of types of power plant equipment for which installation verification might be desired are diesel generators, assembled boilers, turbine-generators, and consoles.

e. Acceptance of Services Only

In certain cases involving procurement of services such as third party inspection; engineering and consulting services; and installation, repair, overhaul, or maintenance work, the purchaser may accept the service by one or more of the following methods:

1) Technical verification of data produced;

2) Surveillance of the activity;

3) Review of verification evidence for conformance to the procurement requirements such as certifications, stress reports, etc.

7. CONTROL OF NONCONFORMANCES AND CORRECTIVE ACTION

a. Nonconformances

Nonconformances are deviations from procurement document requirements. It is essential to correct these nonconformances to prevent further processing, and completion or delivery of power plant items to incorrect procurement requirements. This may be accomplished by documenting the methods for the identification, control, and disposition of nonconformances. Nonconformances to the procurement requirements which fall into the categories listed below should be submitted to the purchaser for approval of the recommended disposition:

1) A technical or material requirement has been violated;

2) A requirement in a supplier's document, which has been approved by the purchaser, is violated;

3) The nonconformance cannot be corrected by the supplier, that is, the item cannot be reworked so that it will meet requirements.

The nonconformance and control methods should contain provisions for the following:

1) Supplier notification to the purchaser. The nonconformance notification should include the supplier's recommended dispostion (such as use-as-is or repair and rework) and the technical justification for the recommendation;

2) The purchaser's disposition of supplier's recommendation;

3) The supplier's verification that the nonconformance has been corrected;

4) Requirements for the maintenance of records for each nonconformance.

b. Corrective Action

The purchaser should verify that the supplier has in fact implemented the corrective action approved by the purchaser. This may be done by verifying that corrective action has been taken. Another method is to review and approve the supplier's written procedures for processing of nonconformances. The purchaser would then verify implementation of the supplier's nonconformance system to obtain assurance that the supplier's nonconformance system is effective.

8. RECORDS

Certain records generated during the procurement cycle should be maintained by the purchaser to provide evidence that the supplier complied with the procurement documents and to track nonconforming power plant items. If the methods used to control and retain these records are specified in written procedures, this work can be done more effectively. The records fall into two categories, supplier-generated records and purchaser-generated records.

Supplier-generated records include those that are required to be submitted to the purchaser, such as code data reports, material certifications, and NDE and test reports. They also include those that the supplier is required to retain for its own files, such as radiographs, welding procedure qualifications, and welder qualifications.

Purchaser-generated records include receiving inspection reports, source verification reports, post-installation test reports, contracts, and procurement documents. Reports which relate to the acceptance of the item or service and the supplier's nonconformance are valuable for developing a history of the supplier's performance to guide future purchases.

The records retained should be legible, identifiable, and retrievable to be of future value. The record control methods should address these requirements.

9. AUDITS

The engineer should perform audits to verify compliance with the quality management program and to measure the effectiveness of the program during all phases of the procurement process. Typically, the essential steps of the audit are:

a. Planning the audit by means of a document which defines the organizations and activities to be audited and the frequency of the audits;

b. Providing audit personnel who are familiar with the types of activities to be audited and who do not have direct responsibilities in the areas being audited;

c. Performing the audit in accordance with guidelines which identify those activities which affect quality;

d. Preparing the audit report which summarizes the audit results and details the nonconformances observed;

e. Submitting the audit report to management responsible for the area audited for review and corrective action for the nonconformances;

f. Re-auditing of nonconforming areas when it is considered necessary to verify implementation of the required corrective action.

See section IV for further discussion of the above steps.

D. MANUFACTURING PRACTICES

1. GENERAL

This section discusses quality management practices relevant to manufacturers of equipment and components. Borrowers and engineers may utilize it to guide them in determining what quality management practices they will require various vendors to follow.

Manufacturers have the advantages of a manufacturing plant in lieu of a construction site. This environment provides a more stable work force and the ability to establish logical and efficient work flow with specialized and orderly work stations. Because of greater permanency, their operation can be continuously improved.

To assure the manufacture of a satisfactory product, capable personnel who are effectively supervised are of prime importance. This, along with good manufacturing facilities, procedures, and planning, is essential for producing a quality product. A quality management program can, when applied to the extent necessary, minimize deficiencies in a cost-effective manner.

Quality management practices which can reduce deficiencies are described in this section. Subjects discussed are as follows:

a. Planning

b. Procedures

c. Document Control

d. Identification and Control of Material, Parts and Components

e. Control of Special Processes

f. Inspection

g. Test Control

h. Inspection and Test Status

i. Control of Measuring and Test Equipment

j. Handling, Storage and Cleaning

k. Nonconforming Items

l. Records

m. Audits

Manufacturers engage in engineering, design, and procurement activities. Subsection B of this section, "Engineering and Design Practices," describes measures which can improve the performance of engineering and design work. Subsection C, "Procurement Practices", provides information useful for procurement activities.

2. PLANNING

Planning is necessary to manufacture a product which complies with procurement document requirements. The purchase order, specifications, and drawings should be reviewed to develop manufacturing plans. Inspection and testing activities required to verify that requirements have been met should be incorporated into these plans.

3. PROCEDURES

Many manufacturing activities are complex and require the development of clear and complete written work procedures to assure adequate control of the activity. Work procedures should include or reference the following information as applicable:

a. Purpose and scope;

b. Responsibilities and qualifications of personnel;

c. Prerequisites to be completed before the activity is begun;

d. Precautions to be observed;

e. Equipment to be used;

f. Detailed description of the activity to be performed, presented in sequential order;

g. Acceptance criteria for the work;

h. Inspections and tests necessary to ascertain that the product meets the requirements of the codes, standards, and project specifications;

i. Forms to be used in accomplishing the work;

j. Records to be maintained.

Procedures should be reviewed by persons with knowledge of the subject and quality requirements, and approved by appropriate management. Procedures should be issued and distributed to involved personnel. They should be controlled to assure that the latest procedures are used. Activities which may require procedures include receipt of material and components, handling and storage of designated items, performance of manufacturing processes, nondestructive testing, etc.

4. DOCUMENT CONTROL

It is important that the proper and current documents are used. The use of wrong documents can significantly affect costs, schedule, and quality since they may not contain the latest information. Work procedures, drawings, specifications, and other documents which prescribe activities affecting quality should be controlled.

Controlling documents and changes thereto should reduce the possibility of using outdated or inappropriate documents.

Following are some important measures that should be incorporated in procedures for document control:

a. Identifying the individuals or organizations responsible for preparing, reviewing, approving, and issuing documents. Also requiring that changes to a document be approved by the individuals or organizations that originally approved the document;

b. Verifying that proper documents are being used. Document indices which identify the latest revisions of documents can be published periodically and all working files brought up to date;

c. Establishing and updating distribution lists;

d. Requiring that the recipients of documents acknowledge receipt of them;

e. Implementing revised documents in a timely manner and removing superseded documents from work areas;

f. Developing checklists to assure that all documentation required by the customer is assembled.

5. IDENTIFICATION AND CONTROL OF MATERIAL, PARTS, AND COMPONENTS

The identification of material or an item must be known to assure it is correctly used. Lack of identification or loss of identification may cause the use of incorrect or rejected materials. When material is received, it should be checked to assure that it is identified as required by the purchasing document. Then its identity should be maintained throughout the manufacturing processes.

When manufacturing processes destroy the identification markings, identification of the material may be recorded on the shop traveler or shop sketch. Material identification methods utilized should not affect the quality of the item. Identification markings should not be located in areas which might interfere with the function of the item such as mating surfaces.

The maintenance of specific identification, such as heat numbers, through the completion of the manufacturing process should be done only when specifically required.

6. CONTROL OF SPECIAL PROCESSES

a. General

A special process is a manufacturing method for which conformance to specifications cannot be readily verified by usual inspections or tests. Certain manufacturing processes can only produce the desired results when they are performed in a very specific manner. Processes of this type require special controls to avoid defects.

Typical special processes are welding, heat treating, bonding, protective coating, and nondestructive testing. These processes usually require controls which include qualification of the method and personnel.

b. Personnel

To control those special processes such as welding which are highly dependent on the skill of the operator, the operators should be certified for the process. Operators should undergo appropriate training and a formal proficiency test designed to demonstrate their capabilities. An effective period of certification should be established, and each individual should be re-certified by retesting at the end of that time period. In most cases, training, testing, and criteria are described in the applicable codes, standards, and specifications. In cases where these do not exist, they should be developed by the manufacturer, and if appropriate, approved by the engineer.

c. Procedures

For those special processes such as heat treating which are highly dependent on the control of the process, the method which will produce the desired results should be determined and documented in a written detailed procedure. The method should then be performed and the results tested to determine if the procedure is satisfactory. Where special tools and equipment are required to perform and/or control the process, these should be specified in the procedure. Requirements for special maintenance, adjustments, and calibration of the tools and equipment should also be specified.

7. INSPECTION

a. Planning

The purpose of inspection is to verify conformance to the quality requirements specified in instructions, procedures, drawings, and specifications. Inspection is performed upon receipt of items at the manufacturing plant and continues through the manufacturing cycle to the preshipment inspection. A written inspection plan will assure that inspections are performed systematically. The inspection plan can be a separate document or part of the shop traveler.

An inspection plan can consist of a flow chart, a diagram, or a narrative description of the sequence of inspection activities. The plan should indicate

the characteristics to be checked, the examination methods to be used, the applicable acceptance criteria, the special instruments required, and the personnel responsibilities for each activity.

b. Receiving Inspection

Items received from suppliers should be inspected as soon as possible after receipt to verify that the items were not damaged during transit, are adequately identified and marked in accordance with contract requirements, and conform to the procurement specifications and drawings. Items should then be clearly identified to indicate their acceptance or rejection status.

c. In-Process Inspection

In-process inspections, or inspections of the work in progress, provide assurance that the required quality is being obtained by the workers. They also discover and remove deficient items from further processing during the manufacturing cycle.

d. Final Inspection

Final inspections are performed on completed items to verify the following:

1) The items meet the specified requirements;

2) Changes initiated after the start of manufacture have been incorporated;

3) Items have not sustained physical damage;

4) All nonconformances have been corrected as required;

5) The items have been properly identified;

6) Items are properly preserved.

e. Preshipment Inspection

In many cases, items are not packaged for shipping immediately after the completion of the final inspection. Accordingly in these cases preshipment inspections should be performed. During these inspections the following are checked:

1) Lack of physical damage;

2) Proper preservation;

3) Proper documentation;

4) Proper identification;

5) Proper packaging for shipping.

f. Inspection Techniques

The inspection techniques selected should be determined by considering the characteristic or parameter to be measured, the work operations being performed, and the requirements of the applicable specifications, codes, and standards.

Indirect control by monitoring the processing methods, equipment, and personnel should be utilized when the physical inspection of completed items is impossible or disadvantageous. Inspection and process monitoring may be required when control is inadequate without both.

g. Mandatory Hold Points

It may be necessary to establish mandatory inspection hold points beyond which work should not proceed without the inspector's approval. These mandatory hold points should be identified on the shop travelers since manufacturing personnel must know when they must call in the inspector.

h. Sampling Inspection

Sampling inspection methods may be used when tests destroy the inspected item or when a large volume of items are to be inspected. The probability of accepting defective items is inherent in the use of sampling plans. Because of this, sampling plans should not be used for items whose use will result in adverse conditions with respect to operability and availability.

i. Inspection Personnel

Inspections should be performed by individuals not directly responsible for performing the work. Supervisors can and should review the work of their subordinates, but for inspections performed to verify that the required quality objectives have been met, independence is necessary.

Inspectors should be certified for the work they are performing by demonstrating their proficiency to assigned examiners. Unless already stipulated in codes and standards, minimum qualification requirements for inspectors should be established by the manufacturer, and if appropriate, approved by the Engineer. A file should be established to identify qualified inspection personnel. When inspectors with the required qualifications are not available, training should be instituted.

j. Inspection Records

Inspection results should be documented for evaluation purposes and to provide evidence that the inspection was performed. Inspection reports should identify the date of the inspection, the inspector, and reference the related drawings and specifications. They should also include the type of observation, the results, the acceptability of the results, and the action taken in connection with any deficiencies found.

k. Monitoring Inspection Results

The inspection results for the various manufacturing processes should be monitored to identify which processes are producing deficiencies. Monitoring may be accomplished by complex methods such as statistical evaluation or simple methods such as plotting the percentage of rejects on a weekly basis. Monitoring will provide a more objective and systematic appraisal than simply relying on the memory of the inspection or manufacturing personnel.

When the analysis reveals that there are numerous problems, the cause of the problem should be determined. When this is known, the steps should be taken to correct the cause.

8. TEST CONTROL

a. General

Tests are frequently performed to determine whether an item meets the quality requirements.

Testing and inspecting are different; however, the basics of planning, performance, personnel, and monitoring are similar. A review of subsection 7, "Inspection", is therefore, useful.

b. Test Program Planning

To verify the satisfactory performance of equipment prior to shipment, a number of tests are often necessary. A test program consisting of a written overall test plan followed by written specific procedures should be developed.

1) Test Plan

The overall test plan should define which tests will be performed and establish the criteria to be satisfied by the test and the acceptance limits for each criteria. The plan should make provisions for retest when modifications, repairs or replacements are made after completion of the initial test.

2) Test Procedures

Test procedures should be prepared as a separate document for components, assemblies, or systems. The test procedures may specify such information as the criteria to be satisfied, the detailed test technique used, the equipment and special tooling required, the acceptance criteria, and the information to be recorded. Preparatory steps such as cleaning, required calibrated instrumentation, and training of personnel should be specified. When special test environments are required, the procedure should specify the method of attaining and maintaining the special environments.

The procedures should be prepared and reviewed to assure compliance with safety standards, prevention of damage to the equipment being

tested, and conformance to the test requirements of the contract.

c. Records

Testing records should be prepared to provide objective evidence that the tests were performed in compliance with approved procedures. The inclusion of appropriate forms for recording test data simplifies the documentation of test results and their evaluation by responsible personnel to assure that the test requirements have been satisfied. The general type of information which should be included in test reports is the same as that for inspection reports. This is discussed in subsection 7, "Inspection."

9. INSPECTION AND TEST STATUS

The status of completion of inspections and tests must be maintained to avoid inadvertent bypassing or duplication of inspection and test work.

Status is best maintained by both physical indications on the items and also written records. Physical indications can be made by use of markings such as stamps, tags, labels, routing cards, etc., attached directly to the item. Written records may consist of shop travelers, inspection records, marked-up copies of drawings or appropriately developed lists. The status should be traceable to the individual inspector who performed the inspections or tests.

Physical indicators can be destroyed, removed or shifted to items which have not yet been inspected or tested. Accordingly, the use of physical indications alone without written records could cause significant and unexpected problems. Thoughtful application of physical indicators and record-keeping methods can produce simple systems which avoid extensive paperwork and are appropriate to the circumstances.

The status information may be recorded on shop drawings or shop travelers to identify those items which have satisfactorily passed the required inspections and tests as well as those which have failed and require rework, reinspection or retest.

10. CONTROL OF MEASURING AND TEST EQUIPMENT

a. Control System

Inaccurate measuring and test equipment can cause significant problems since they can provide erroneous measurements. A system is needed to control measuring and test equipment. Equipment such as micrometers, gage blocks, hardness testers, thermometers, pressure gages, and jigs require controls. Rulers, tape measures, levels, etc., need not be controlled if they are utilized to make measurements with tolerances that fall within the accuracy of these devices.

Tools, gauges, instruments, and other inspection, measuring, and test equipment and devices which are needed to perform activities affecting quality must first be of the proper type, range, and accuracy to perform the required function.

The equipment must then be calibrated to assure that it produces accurate measurements. The equipment should be physically identified by unique serial (or other) numbers, calibrated in accordance with appropriate procedures, and adjusted to an accuracy sufficient for its intended use. Calibrations should be performed with reference standards which are traceable to the National Bureau of Standards.

Since the accuracy of equipment may change during use, equipment should be re-calibrated at scheduled intervals. The calibration interval for each item should be based on the type of equipment, required accuracy, and its frequency of use. Special calibrations should be required if it is suspected that the equipment was damaged or if questionable results are obtained.

A calibration label should be placed on the equipment to permit the user to determine if the equipment is within its calibration interval. The label should bear the calibration date, the last date the equipment can be used, the serial number of the equipment, and the name of the person or company which performed the calibration.

The manufacturer may perform the calibrations or use the services of an independent laboratory. The

initial calibration of equipment can usually be performed by the equipment supplier if this is stipulated in the purchase order. A certificate of calibration should also be requested.

Since the reference standards used to calibrate the measuring and test equipment may lose their accuracy, they should also be re-calibrated periodically.

Simple record systems should be developed to record the status of the equipment and the calibration results obtained. These systems will aid in the prompt withdrawal from service of equipment when it needs re-calibration.

b. Impact on Previously Inspected or Tested Items

When equipment used for inspections and tests is found to be out of calibration, the validity of the previous inspection or test data becomes suspect. Because of this, the acceptability of the items inspected or tested with the equipment also becomes suspect. When discrepancies in equipment are found at calibration, the equipment should be corrected and the items which had been inspected or tested with the equipment, should be reinspected or retested to determine their acceptability.

11. HANDLING, STORAGE AND CLEANING

a. Handling

The quality of items may be deteriorated by improper handling. Special precautions may be required during handling or lifting of items to prevent damage because of weight, size, susceptibility to shock, damage, or other considerations. A general handling procedure which contains sound handling practices should be prepared. Assurance should be obtained that operators of handling and lifting equipment are competent. Where special precautions are required, specific handling procedures should be developed.

b. Storage

The quality of items may deteriorate during storage. Written instructions should advise receiving personnel as to which items require indoor storage and which items can be stored outside. Equipment requiring special environmental conditions for storage should also be identified.

Periodic inspection of all stored items may detect deterioration or damage, and permit the timely correction of the deteriorating condition and replacement of the deteriorated items.

Some items may require periodic tests or checks during storage. An organized program for accomplishing this should be instituted.

c. Cleaning

Improper cleaning can deteriorate the quality of an item by not sufficiently cleaning it or even damaging it. The preparation and implementation of special cleaning procedures which define cleaning methods and cleanliness requirements will help prevent this.

d. Preservation, Packaging and Shipping

To avoid damage and deterioration during shipment or during subsequent storage at the construction site, preservation and packaging requirements should be established and documented for personnel performing this work.

12. NONCONFORMING ITEMS

It is important to prevent the use of items which have been determined to be unacceptable. An effective and positive system for controlling these items should include procedures for the identification, segregation, and disposition of the nonconforming items.

Nonconforming items can be identified by the use of tags or other markings, or the placement of these items in containers which are so marked.

It is useful to segregate these marked items by placing them in holding areas which are remote from acceptable

items. This segregation reduces the possibility of their use.

The disposition of a nonconforming item may be to accept it "as is," to scrap it, or to repair or rework it so that the applicable requirements are met. The responsibility and authority for the disposition of nonconforming items should be defined to assure that these important decisions are controlled.

13. RECORDS

Records provide evidence that the manufacturing activities were satisfactorily performed. Examples of records are procedures described in this section of the manual, personnel qualification records, inspection and test records, and nonconformance reports. The records generated should be collected, checked for legibility, stored, and maintained. They should also be identifiable and retrievable for auditing manufacturing activities.

14. AUDITS

Manufacturers should perform audits to verify compliance with their quality management program and to measure the effectiveness of the program during all phases of the manufacturing process. Typically, the essential steps of the audits are as follows:

a. Planning the audit by means of a planning document which defines the organizations and activities to be audited and the frequency of the audits;

b. Providing audit personnel who are familiar with the types of activities to be audited and who do not have direct responsibilities in the areas being audited;

c. Performing the audit in accordance with guidelines which identify those activities which affect quality;

d. Preparing the audit report which summarizes the audit results and details the nonconformances observed;

e. Submitting the audit report to management responsible for the area audited for review and corrective action for nonconformances;

f. Re-auditing of nonconforming areas when it is considered necessary to verify implementation of the required corrective action.

See section IV for further discussion of the above steps.

E. CONSTRUCTION PRACTICES

1. GENERAL

This section relates to quality management activities during construction. A construction site environment is very different from a manufacturing plant or engineer's office. By its nature, it is a temporary facility with changing personnel as dictated by the changing scope of work.

To assure that a satisfactory power plant is constructed, proper planning, supervision, and an adequate number of qualified personnel are essential. Qualified personnel, good construction practices and procedures as well as verification that these practices and procedures have been implemented are needed to produce a quality power plant.

Properly applied quality management programs will minimize deficiencies and reduce the adverse effects of deficiencies on costs and schedule. The selection of quality management practices should be based on the complexity of the structures and systems constructed and the complexity of the construction processes utilized. Quality management practices which can reduce deficiencies are described in this subsection. The following subjects are discussed:

a. Planning

b. Procedures

c. Document Control

d. Identification and Control of Material, Parts, and Components

e. Control of Special Processes

f. Inspection

g. Test Control

h. Inspection, Test, and Operating Status

i. Control of Measuring and Test Equipment

j. Handling, Storage, and Cleaning

k. Nonconforming Items

l. Records

m. Audits

Constructors typically engage in design work such as the preparation of detail working drawings. Refer to subsection B, "Engineering and Design Practices," of this section which describes measures that can be taken to reduce deficiencies in this area.

Constructors purchase materials and, at times, equipment for installation in the power plant. Subsection C, "Procurement Practices," provides information useful in reducing deficiencies in this area.

Since the engineer must contractually perform inspections to assure that the construction of the plant is satisfactory, reference to the inspection and test control portions of this subsection will be useful.

2. PLANNING

Planning of large and complex projects such as power plants is essential. Construction should be planned and defined to ensure that the methods used are consistent with best practices. The sequence should be defined so that the operations are performed in the best order to ensure the proper interaction of the operations. Acceptance criteria define the required quality and should be provided to the craftspeople and the inspectors. Good planning takes into account the need for the preparation and control of procedures and work instructions necessary to comply with the requirements for installation, inspection, and testing. Planning should include the review of specifications, drawings, material lists, construction work plans, and schedules to assure that installation, inspection, and testing activities have been incorporated. Planning should also assure that these activities can be accomplished, as specified, and that time and resources are sufficient to accomplish the scheduled construction in a cost-effective manner.

3. PROCEDURES

Many construction operations are of a complexity which warrants the preparation of written construction descriptions or procedures to define how a construction operation is to be controlled. The existence and availability of clearly written procedures or descriptions permits the work to proceed more smoothly and effectively than otherwise would be the case. These documents also greatly facilitate the engineer's inspection of the work performed.

Descriptions should include the following information:

a. Purpose and scope of an activity;

b. Who is responsible;

c. What has to be done to complete it.

Procedures are used to establish greater control and should include or reference the following information as applicable to the activity:

a. Purpose and Scope;

b. Responsibilities and qualifications of personnel;

c. Prerequisites to be completed before the activity is begun;

d. Precautions to be observed;

e. Equipment to be used;

f. Detailed description of the activity to be performed, presented in sequential order;

g. Acceptance criteria for the work;

h. Inspections and tests necessary to ascertain that the installation meets the requirements of the codes, standards, and project specifications;

i. Forms to be used in accomplishing the work;

j. Records to be maintained.

The need for and cost effectiveness of written descriptions or procedures should be based on the following:

a. Complexity of the construction operation -- The performance of simple or routine activities can be planned by the worker or supervisor. With added complexity, the planning will require the knowledge of skilled construction specialists or engineers.

b. Complexity of structure, system, or component -- For complex structures, etc., planning will require someone with knowledge of the complete construction sequence and the importance of the different characteristics of the structure. Accordingly, written procedures would prove useful.

Procedures and descriptions should be reviewed by persons with knowledge of the subject and quality requirements, and approved by appropriate management. Subsequent to approval, the procedures should be issued and distributed to all involved personnel. All procedures should be controlled to assure that the latest ones are used. Methods for controlling procedures are described in subsection 4; "Document Control."

Construction activities which may require procedures include, but are not limited to the following: receipt of material and components, handling and storage of designated items, performance of civil and structural work, installation of mechanical and electrical equipment, installation of instrumentation and controls, installation of piping and related materials, and erection of major equipment such as the steam generator and turbine generator components. Examples of specific procedures include electrical cable pulling, large turbine pedestal concrete placement, structural steel placement, bolting, field pipe bending, and flushing and cleaning.

Sometimes, procedures are prepared for special situations. An example would be a procedure describing trial runs or tests of construction processes prior to the start of the construction activity to avoid problems during actual construction. This applies to processes which are familiar as well as those that are new to the contractor. As an example, construction problems can be avoided if the construction procedure states that a soils backfill test bed is to be set up to determine the

number of compactor passes required to achieve the required soil density.

4. DOCUMENT CONTROL

The use of wrong documents can significantly affect costs, schedule, and quality, since they may not reflect the latest information. This applies to work instructions, drawings, specifications, and numerous other documents which prescribe activities affecting quality. The establishment of measures to control the issuance and disposition of these documents and changes to them will help prevent this type of problem. Procedures should be prepared to assure that the documents are reviewed and approved for adequacy by authorized personnel, and that they are distributed to and used at locations where the prescribed activity is performed.

The control of the documents and changes thereto should reduce the possibility of the use of outdated or inappropriate documents in construction. Important measures that should be incorporated in construction procedures for document control are as follows:

a. Identification of individuals or organizations responsible for preparing, reviewing, approving, and issuing documents and revisions thereto. Also requirements that revisions to documents be approved by the group that originally approved the document;

b. Verification that proper documents are being used. This can be accomplished by maintenance of document indices which identify the latest revision of documents. These indices are published periodically (e.g., monthly for most work) and all working files should be brought up to date;

c. Establishment and updating of distribution lists;

d. Distribution of documents with recipient's acknowledgement of receipt of the document;

e. Implementation of revised documents in a timely manner and removal of superseded documents from work areas;

f. Assurance that all required documentation is assembled in each documentation package for a

specific structure, system, or component. This can be accomplished by means of a checklist;

g. Documentation of field changes made to approved engineering and design documents. These field changes should be subjected to review and acceptance by the originating organization.

5. IDENTIFICATION AND CONTROL OF MATERIAL, PARTS, AND COMPONENTS

For the proper material or item to be installed, its identification must be known. Lack of identification or loss of identification may cause the use of incorrect or rejected materials during installation. The first step is to assure during receipt inspection that the material is, in fact, identified as required by contract, drawings, or specifications. The second step is to maintain this identity throughout the construction process. Items or their containers may be tagged, marked, etc. When construction processes destroy the identification markings, identification of the material may be recorded on documents such as a field traveler or a "record copy" of a drawing. Material identification methods should not affect the quality of the item being identified. For example, identification markings should not be located in areas such as mating surfaces, threads, or other areas which might interfere with the function of the item.

Material identification should not be confused with material traceability. The latter requires that each individual item have a unique identifier to differentiate apparently identical items which come from different lots. An example of this is the heat numbers found on metal products. When traceability is warranted, the start and finish points of the trace, the items involved, and the extent of records required should be carefully defined. Because the cost of traceability is high, this should be done only in isolated cases for very significant reasons.

6. CONTROL OF SPECIAL PROCESSES

a. General

Special construction processes are those which cannot be readily verified as fully conforming to specifications by usual inspection and test methods. They tend to be complex and require skill to perform. While it is possible to determine by

inspection that equipment has been placed in the proper location, it is not possible to verify the acceptability of welds by inspection. Consequently, quality can be assured only by monitoring the process as it is performed. Monitoring can assure that craftspeople are controlling the variables of the process within prescribed limits. Typical special processes utilized in construction are stress relieving of pipe, nondestructive examination, welding, and brazing. Certain painting and bonding processes also fall into this category.

It is necessary to document in advance the procedures that will be used to perform special processes, and to establish qualifications for craftspeople when the process is dependent upon their manual skills. Without these measures, defects are difficult to control.

b. Personnel

For those special processes such as welding and brazing, which are highly dependent upon the skill of the operator, operators should be certified for the process. Craftspeople should undergo appropriate training and a formal proficiency test designed to demonstrate their capabilities. An effective period of certification should be established and each craftsperson should be re-certified at the end of the period by retesting. In most cases, training, testing, and criteria are described in the applicable codes, standards, and specifications. In cases where these do not exist, they should be developed by the engineer or the contractor, as appropriate.

c. Procedures

For those special processes such as stress relieving and radiography, which are highly dependent on the control of the process, the method which will produce the desired results should be determined and documented in a written, detailed procedure. The method should then be performed and the results tested to determine if the procedure is satisfactory. Where special tools and equipment are required to perform and/or control the process, these should be specified in the procedure. Requirements for special maintenance, adjustments,

and calibration of the tools and equipment should also be specified.

7. INSPECTION

The purpose of an inspection is to detect and determine the disposition of nonconformances in quality and to provide evidence that contract requirements are met. Inspections are performed by engineers to fullfill their REA Form 211 responsibility of assuring a satisfactory power plant for the borrower. Constructors should also perform inspections for the same purposes.

a. Planning

The function of inspection is to verify conformance to the instructions, procedures, drawings, and specifications for accomplishing activities affecting quality. Inspection is performed by means of examination, observation, or measurements during receipt of items at the construction site and continues through storage, installation, and testing of items or systems. In order to perform inspections systematically, planning the inspections in accordance with an inspection plan is recommended. An inspection plan is prepared either as a separate document or as an integral part of the construction procedure.

An inspection plan should consist of a flow chart, a diagram, or a narrative description of the sequence of activities for inspecting. The plan should indicate the characteristics to be checked, the examination methods to be used, the applicable acceptance criteria, special tooling required, the personnel responsibilities for each activity, and the provisions for recording of inspection results.

b. Receiving Inspection

It is advisable that incoming items be inspected as soon as possible after receipt to verify that the items:

1) Were not damaged during transit;

2) Are adequately identified and marked in accordance with contract requirements;

3) Are complete, that is, all parts, components, documents, etc. are present;

4) Conform to the applicable specifications and drawings.

After completion of the receiving inspection, the items should be clearly identified to indicate their acceptance or rejection status prior to installation.

c. In-Process Inspection

In-process inspection during the installation and construction of items provides assurance that the required quality is being obtained in accordance with approved procedures. It also assures that deficient items or systems are found and removed from further processing early in the construction of the plant. This reduces the cost of rework. Inspections of the work in progress should be performed to verify that items are being installed, assembled, and constructed in compliance with the contract, and the latest approved specifications, drawings, installation procedures, codes, and standards.

Typical in-process inspections include verification of the following:

1) Location and orientation of equipment

2) Leveling and alignment

3) Clearances and tolerances

4) Tightness of connections and fastenings

5) Fluid levels and pressures

6) Absence of leakage

7) Cleanliness

8) Identification

9) Adequacy of housekeeping

10) Welding operations

11) Concrete measuring, mixing, transporting, placements, curing, and protection

d. Final Inspection

Final inspections verify that the completed systems and items are in conformance with specified requirements. These inspections also verify the operational readiness of systems and items. Examples of things checked during final inspections are as follows:

1) Installation has been made in accordance with specified requirements;

2) Workmanship is satisfactory;

3) Items have not sustained external physical damage;

4) All nonconformances have been corrected as required;

5) Safety features are being used and comply with applicable codes and regulations;

6) Item identification has been preserved throughout the installed systems.

e. Inspection Techniques

The inspection techniques selected should be determined by considering the characteristic or parameter to be measured or the work operations being performed. The basic criteria for the selection of inspection techniques and processes are the requirements of the applicable specifications, codes, and standards.

When the physical inspection of completed items is impossible or disadvantageous, indirect control by monitoring of the processing methods, equipment, and personnel can be performed. Inspection and process monitoring should be performed when control is inadequate without both.

f. Mandatory Hold Points

At times it is appropriate to establish mandatory inspection hold points. The work is not to proceed beyond these points without the approval of the inspector. These mandatory hold points should be identified in work schedules. These schedules

should be issued to the construction work force, since they must know when to advise the inspection force and await the completion of a designated inspection. Since mandatory hold points are preplanned, they should not delay construction because the construction progress would be monitored to assure that inspection personnel are available at the appropriate time. Coordination between construction and inspection personnel of mandatory hold points also helps to avoid construction delays.

g. Sampling Inspection

Sampling inspection methods may be used when destructive testing is required to verify the adequacy of the work performed. It may also be used when inspection history indicates that a reduction in inspection will not jeopardize the quality of the item, or when a large volume of items are to be inspected.

Any sampling plan used must provide valid confidence that it will achieve adequate quality. Because of the nature of sampling plans, defects may be present in the items accepted by sampling inspection. When the use of these defective items would effect the operability and availability of the plant, sampling plans should not be used.

h. Inspection Personnel

Inspections should not be performed by the supervisors of the personnel performing the work being inspected. They should be performed by individuals not directly responsible for performing the work. This should in no way be construed to mean that supervisors should not inspect the work of their subordinates. In fact, it is most important that they do so. However, for inspections performed for the purpose of verifying that the supervisor and subordinates have met the required quality objectives, independence is necessary.

An effective quality management program for a power plant would include an engineer's inspection group and inspection groups from the various constructors. The borrower might also choose to have its personnel perform inspections. Each inspection group would be directly responsible to

its own organization. Although they might inspect the same areas of construction, each inspects for different reasons. Constructor inspectors determine if the craftspeople have performed properly. After they have completed this for a segment of work, the engineer's inspectors determine if the constructor's inspectors adequately accomplished their mission. The borrower's inspectors subsequently check on the adequacy of the engineer's inspection work.

Inspectors should be qualified for the work they are performing by demonstrating their proficiency to the appropriate level of management. It is not necessary that the inspector be thoroughly capable of performing the work that is being inspected. For example, an inspector need not be a carpenter to determine whether the carpenters have constructed the concrete forms to the required dimensions. The ability to take measurements is sufficient for this particular inspection activity.

Unless stipulated in codes and standards, minimum qualification requirements for inspectors should be established by the engineer or constructor in accordance with procedures. A file should be established to identify qualified inspection personnel. When inspectors with the required qualifications are not available, training should be instituted.

i. Inspection Records

Documentation of inspection results is important for evaluation purposes and to provide evidence that the inspected items or systems are acceptable. Checklists which list each inspection criteria should be prepared to document the results of the inspection. At a minimum, they should identify the date of the inspection, the inspector, reference appropriate drawings and specifications, and note the type of observation, the results, the acceptability of the results, and the action taken in connection with any deficiencies noted.

j. Monitoring Inspection Results

The inspection results for the various construction processes should be monitored to keep a running track of those processes which are producing deficiencies. This monitoring is often called trend analysis. These trend analyses may be performed by complex methods (e.g., statistical evaluation) or simple methods (e.g., plotting the percentage of rejects on a weekly basis). Whatever the method selected, it is important to perform these trend analyses, since they provide a much more objective and systematic appraisal than that achieved by simply relying upon the memory of the inspection or construction personnel.

When the analysis reveals that there are numerous problems, the first step is to determine the cause of the problem. When this is known, steps should be taken to correct the cause. It is not sufficient to simply increase inspection, since this will only separate the good from the bad. Increased inspection will increase costs because the money spent on work which was rejected can not be retrieved and the increased volume of inspection work costs more money. The greater amount of rework also affects the schedule, since less acceptable work is completed.

8. TEST CONTROL

a. General

The previous subsection discussed the verification of quality requirements by inspection methods. Frequently, a test is performed in lieu of, or in addition to, an inspection to determine whether an item or system has met its quality requirements. Examples of tests are civil/structural tests, hydrostatic and other mechanical tests, electrical check-out and testing, functional tests, and performance/efficiency tests.

Although the specifics of testing and inspecting differ, the basics of inspection planning, performance, personnel, and monitoring are similar for testing (see subsection 7, "Inspection").

b. Test Program Planning

To verify the satisfactory performance of systems prior to the start of commercial operation of a power plant, a program of functional tests, preoperational tests, and operational tests is necessary. A test program consists of a written overall plan followed by written specific procedures.

1) Test Plan

Test planning should be done with full consideration of coordinating with the installation and inspection processes and sequence. This planning in the form of a test plan should establish the criteria to be satisfied by the test and the acceptance limits for each criteria. The plan should make provisions for retest when modifications, repairs, or replacements are made after completion of the initial test. The extent of retest is based on verifying the acceptability according to the same criteria as was used in the initial test.

2) Test Procedures

Test procedures should be prepared as a separate document for components, assemblies, or systems. The test procedures may specify such information as the criteria to be satisfied, detailed test technique used, equipment and special tooling required, acceptance criteria, and the information to be recorded. Preparatory steps such as cleaning, required calibrated instrumentation, and training of personnel are identified and detailed. When the test is conducted in special environments, the procedure should specify the method of attaining and maintaining the special environments.

The procedures are prepared and reviewed to assure compliance with safety standards, prevention of damage to the system being tested, and conformance with the contractual test requirements.

c. Records

Test results should be documented to permit the evaluation of the test and its results. Appropriate forms for recording test data should also be included in the test procedures. This simplifies both the documentation and evaluation of the test results. The results must then be evaluated by responsible personnel to assure that the test requirements have been satisfied. The general type of information which should be included in test reports is the same as that for inspection reports. This is discussed in subsection 7, "Inspection."

9. INSPECTION, TEST AND OPERATING STATUS

a. General

It is important to keep complete and accurate information as to the status of inspections and tests performed on items and systems. This is needed to avoid inadvertent bypassing and duplication of inspection and test work.

b. Inspection and Test Status

Status is best maintained by both physical indications on the items and written records. Physical indications can be made by the use of markings such as stamps, tags, labels, routing cards, etc. attached directly to the item. Written records may consist of field travelers, inspection records, marked-up copies of drawings or appropriately developed lists. The status should be traceable to the individual inspector who performed the inspections or tests.

Sole reliance on physical indication methods, to the exclusion of written records, could cause significant and unexpected problems. It is important to recognize that the physical indicators can be destroyed, removed, or shifted to items which have not yet been inspected or tested. Thoughtful application of physical indicators and record-keeping methods can produce simple systems which avoid extensive paperwork and are appropriate to the circumstances.

The status information may be recorded on drawings or other appropriate documents to identify those items which have satisfactorily passed required inspections and tests and also those which have failed and require rework and re-inspection or retest.

It is very important that a positive system for identifying the inspection and test status of items and systems be employed. If physical indicators or written records are not available, it should be assumed that inspections and tests were not performed. A negative system would be one where only deficiencies would be identified, and it is assumed that unmarked items would have been proved to be acceptable. Normally, a negative system is not satisfactory, since there is no distinction between uninspected/untested items and those which have been accepted.

c. Operating Status

During the preoperational and operational stages, it is equally important to maintain indications of the operating status of the plant systems and components. This includes measures such as tagging of valves and switches to prevent inadvertent operation of a partially or fully installed system which can damage equipment or harm personnel. These measures are taken to identify possible hazards. The physical marking of equipment should be backed up with written records.

10. CONTROL OF MEASURING AND TEST EQUIPMENT

a. Control System

Significant problems can occur if a decision is based on results obtained from measuring and test equipment which does not provide accurate measurements. Because of this a control system is needed for measuring and test equipment. Equipment such as voltmeters, radiographic penetrameters, thermometers, welding equipment, ammeters, pressure gages, and timing devices should be included in the system. The system should not include such items as rulers, tape measures, levels, etc., if they are utilized to make measurements with tolerances that fall within the accuracy of these devices.

This type of control system starts with the selection of the tools, gauges, instruments, and other inspection, measuring and test equipment or devices which are needed to perform activities affecting quality. The equipment must be the proper type, range, and accuracy to perform the required function.

Next, the equipment must be calibrated to assure that it will produce accurate measurements. Calibration involves physically identifying the equipment by unique serial (or other) numbers, calibrating the equipment in accordance with appropriate procedures, and adjusting the equipment to an accuracy sufficient for its intended use. Calibrations are performed with reference standards which are traceable to the National Bureau of Standards.

Since the accuracy of equipment may change during use, equipment should be re-calibrated at scheduled intervals. The calibration interval for each item should be based on the type of equipment, required accuracy, and frequency of use. The procedure should also provide for special calibration if the test equipment is damaged or if questionable results are obtained.

Placing a calibration label on the equipment permits the user to know whether the equipment is within its calibration interval. The user can therefore avoid using equipment that has passed its calibration interval. The label should bear the calibration date, the date after which the equipment can no longer be used, the serial number of the equipment, and the identity of the person or company which performed the calibration.

Constructors using measuring and test equipment may perform their own calibration work or use the services of an independent laboratory. The initial calibration of equipment can usually be performed by the supplier if this is stipulated when the equipment is purchased. A certificate to this effect will provide the positive control that is needed.

The reference standard used to calibrate the measuring and test equipment may lose its accuracy. For this reason, the reference standards used to

calibrate construction and inspection equipment should be included in the control program.

Simple record systems can be developed to record the status of the equipment, the calibration results obtained, and aid in the prompt withdrawal from service of equipment which needs re-calibration.

b. Impact on Previously Inspected or Tested Items

When equipment used for inspections and tests is found to be out of calibration, the validity of the previous inspection or test data becomes suspect. Because of this, the acceptability of the items inspected or tested with the equipment also becomes suspect. When discrepancies in equipment are found at calibration, the equipment should be corrected and the items which had been inspected or tested with the equipment should be reinspected or retested to determine if all applicable requirements were met. Interestingly, this investigation may reveal that items which were rejected should not have been rejected, since the items were acceptable although the equipment indicated that they were not.

To avoid a situation where a massive number of items must be retested after an investigation of this type, it is prudent to keep calibration intervals short.

11. HANDLING, STORAGE AND CLEANING

a. Handling

The quality of items may deteriorate by improper handling. Special precautions may be required during handling or lifting of items to prevent damage because of weight, size, susceptibility to shock, damage, or other considerations. The development and issuance of a general handling instruction which contains sound handling practices is useful. Additionally, the constructor should assure that operators of handling and lifting equipment are competent, experienced, and properly supervised. Where special precautions should be taken, specific handling procedures should be developed to specify the practices to be followed.

b. Storage

The quality of items may deteriorate during storage. Instructions should be developed and issued to advise receiving personnel as to which items require indoor storage and which items can be stored outside. Certain equipment may require special environmental conditions for storage. These should also be made known to the receiving personnel.

Periodic inspection of all stored items, both indoors and outdoors, may detect deterioration or damage, and thereby permit the timely correction of the defects or the re-purchase of the items. When deterioration or damage is found, the conditions which caused it should be determined and corrected.

Some items such as electrical motors may require periodic operation, tests, or checks during storage. An organized program for accomplishing this should be instituted.

c. Cleaning

Improper cleaning can deteriorate the quality of an item or system. The cleaning process may not sufficiently clean the item or system. At other times, the cleaning process may, in fact, damage the items or systems. The preparation and implementation of special cleaning procedures which define the cleaning method and the cleanliness requirements will help prevent this.

12. NONCONFORMING ITEMS

It is important to prevent the use or installation of items which have been determined to be unacceptable. An effective and positive system for controlling these items will include procedures for the identification, segregation, and disposition of the nonconforming items.

Nonconforming items can be identified by the use of tags or other markings, or the placement of these items in containers which are so marked.

It is useful to segregate these marked items by placing them in holding areas which are remote from acceptable items. This segregation reduces the possibility of their use.

The disposition of a nonconforming item may be to accept it "as is," to scrap it, or to repair or rework it so that the applicable requirements are met. The responsibility and authority for the disposition of nonconforming items should be defined to assure that these important decisions are controlled.

13. RECORDS

Records provide evidence that the construction activities were satisfactorily performed. They also provide information to track nonconforming power plant items during construction operations. The procedures described in this section of the manual, personnel qualification records, inspection and test records, and nonconformance reports are a few examples of records. The records generated should be collected, checked for legibility, stored, and maintained. They should also be identifiable and retrievable for auditing construction activities.

14. AUDITS

The engineer should perform audits on constructors to verify compliance with the quality management program and to measure the effectiveness of the program during all phases of the construction process. In addition, constructors may perform audits on their own operations and on their subcontractors, as appropriate. Typically, the essential steps of the audit are as follows:

a. Planning the audit by means of a planning document which defines the organizations and activities to be audited and the frequency of the audits;

b. Providing audit personnel who are familiar with the types of activities to be audited and who do not have direct responsibilities in the areas being audited;

c. Performing the audit in accordance with guidelines which identify those activities affecting quality;

d. Preparing the audit report which summarizes the audit results and details the nonconformances observed;

e. Submitting the audit report for review and corrective action for the nonconformances by management responsible for the area audited;

f. Re-auditing nonconforming areas when considered necessary to verify implementation of the required corrective action.

See section IV for further discussion of the above steps.

SECTION IV

EVALUATING A QUALITY MANAGEMENT PROGRAM'S EFFECTIVENESS

A. INTRODUCTION

The effectiveness of a quality management program is evaluated in terms of the success in realizing the program objectives. The program's effectiveness discussed in this section can be determined by:

1. Quality audits

2. Measuring quality costs

3. Measuring the frequency of rejected work

B. AUDITS

1. GENERAL

Audits are performed to verify compliance with all phases of the quality management program. An audit is not a surveillance or an inspection which is performed for the purpose of process control or acceptance of the product.

Audits are generally performed by the engineer but they can also be performed by borrowers and/or contractors, as appropriate, during engineering, procurement, manufacturing, and construction phases of a power plant. The methods presented in this manual are applicable to both internal and external audits. Internal audits are those performed within your own organization. External audits are those you perform on outside organizations such as suppliers and consultants.

Audits should be performed periodically in a preplanned, controlled and orderly manner to verify conformance with all aspects of the quality management program by appropriately experienced and trained personnel. The results should be documented, reviewed by management, and the necessary action taken to correct any nonconformance revealed during the audit.

Whenever an audit indicates substantial deviation from the program, consideration should be given to looking carefully at the program itself for possible modification.

2. AUDIT SCHEDULING

The audits should be regularly scheduled on the basis of the status and importance of work activities. They are normally conducted at the beginning of a project, at six month intervals during peak periods, and near the completion of work.

Regularly scheduled audits should be supplemented by additional audits when any of the following conditions occur:

a. It is suspected that the quality of the item is in jeopardy due to deficiencies in the quality management program;

b. Significant changes are made to the quality management program such as extensive reorganization or procedure revisions;

c. Independent assessment of program effectiveness is considered necessary;

d. It is necessary to verify implementation of required corrective action.

3. AUDIT PLANNING

Audits are performed in accordance with checklists used by the auditor to enter all pertinent areas in an orderly sequence and with a minimum of wasted time and effort. Without a checklist, the auditor enters an area with only the requirements and/or working procedures at hand. It is difficult to leaf through the requirements, documents, or procedures on the spot and pick out the specific items that can be checked at that point. It is all too easy to leave the area only to find, often when it is entirely too late to remedy the oversight, that one or more significant points have been overlooked. The audit checklist provides a useful means of determining, at any time, what was actually done during the audit and what the auditor found.

4. AUDIT PERSONNEL

To avoid conflicts of interest, audits are performed by personnel who do not have direct responsibilities in the areas being audited. Personnel performing audits should be competent and have sufficient authority and organizational freedom to make the audit process meaningful and effective. When specific technical expertise is required in the performance of an audit, it is desirable to select appropriately qualified technical personnel to participate in the audit.

5. AUDIT REPORTING

Audit results should be documented in an audit report which is transmitted to management personnel having responsibility for the activity audited. An audit report includes the following:

a. Description of the audit scope;

b. Identification of the auditors;

c. Personnel contacted during the audit;

d. Summary of audit results;

e. Details of specific nonconformances observed;

f. Recommendations for correcting quality program nonconformances or improving the program;

g. Date of required response by the audited organization.

The report should be distributed to the management of both the audited and auditing organization and issued within 30 days after the audit.

6. AUDIT FOLLOWUP

Management of the audited activity should review and investigate all audit nonconformances stated in the audit report to determine and schedule appropriate corrective action, along with the action,to prevent recurrence (including, where necessary, changes to the quality management program). They should respond as requested by the audit report, documenting the results of their review and investigation. The response should be made within 30 days of the issuance of the report and

should clearly state the corrective action taken or planned and indicate how they intend to prevent recurrence. In the event that corrective action cannot be completed prior to the issuance of the response, a scheduled date for the implementation of the corrective action should be included.

The audited activity should provide a follow-up report stating the corrective action taken and the date the corrective action was completed. They should also take appropriate action to assure that corrective action is accomplished as scheduled.

Follow-up action should be taken by the audit team leader for the following reasons:

a. To obtain a written response to the audit report, when a response is required and it has not been submitted;

b. To evaluate the adequacy of the response;

c. To assure that corrective action and means of preventing recurrence are identified and scheduled for each nonconformance;

d. To verify that corrective action is accomplished as scheduled.

C. EVALUATING EFFECTIVENESS BY MEASURING QUALITY COSTS

A frequent reaction to the establishment of a quality management program is the implication and assumption of increased costs. It is certainly true that if quality management methods have not been practiced, then some increased inital cost can be expected. Where a high degree of confidence is required, management should understand and expect this increase.

The identification and evaluation of the quality costs can, however, provide perspective in evaluating the effectiveness of a quality management program. Some of the functions contributing to quality management cost are as follows:

1. Direct and overhead costs of persons performing quality management functions;

2. Direct and indirect labor for such functions as inspection, testing and calibration;

3. Functional and preoperational test costs;

4. Test and inspection equipment costs;

5. Design review costs;

6. Design and drafting checkers' costs;

7. Equipment pre-installation testing;

8. Receiving inspection;

9. Maintenance of records;

10. Vendor evaluation and analysis.

Certain additional costs worth evaluating are those that reflect a failure to secure adequate quality, such as the following:

1. Rejected and scrapped material;

2. Repair and rework;

3. Guarantee and post delivery deficiency correction.

In other industries, a reasonably reliable body of data is available which shows that the cost of preventing failures is substantially less than the combined cost of locating and identifying the failures; recording, analyzing, and reporting the failures; and, repairing or replacing the defective material or services. Since a planned and systematic quality management program is aimed at detection and prevention of failure, cost analysis tools can be used to provide management with specific examples where failure reduction will more than offset added preventive costs. Where a sufficient body of data is available, a statistical "break-even point" can be established. In this relation, the break-even point can be defined as that point at which the cost of failure prevention equals the cost of failures, including parts repair/replacement and identification, and recording and evaluation of failures.

To be useful, cost data need not necessarily involve elaborate accounting systems, but can be as simple as calculating the cost of rework as a percentage of the total cost of work performed. This type of information, with the assumptions documented, the conclusions reached, and the recommendations for preventive action stated, can form a sound basis for management to make decisions concerning modification of the quality management program.

D. EVALUATING EFFECTIVENESS BY MEASURING THE FREQUENCY OF REJECTED WORK

The effectivness of a quality management program can be measured by analyzing its results. Since the purpose of the program is to reduce defects in a cost effective manner, the effectiveness of the program can be gaged by analyzing reports of unacceptable quality. A simple analysis system can be instituted for this purpose. Such a system consists of determining, by use of inspection and test reports, the percentage of rejected work for each work activity over a stated period of time, usually a month. Examples of construction work activities would be pipe welding, cable laying, etc.

Such a system should incorporate the following general requirements:

1. Adaptability to all types of work activities;

2. Simplicity and low cost through the use of existing inspection and test data;

3. Representation of the true performance of each work activity;

4. Observation of trends in the quality of the work;

5. Determination by management when follow-up action is required.

Systems which also include methods for classifying defects as to seriousness provide a more representative picture of the effectiveness of the program. Typical classifications are critical defects, major defects, and minor defects based on the consequence of defects if they remained undetected.

A quality management program, to be effective, must provide a method for the continued improvement of quality. Accordingly, after the effectiveness of the program is evaluated, the logical step is to use this data to initiate changes to the program. The preparation and distribution of a report of construction work activities with repetitive problems can help focus attention on problem areas.

This report, which identifies the specific problems needing corrective action, can be used by those responsible for performing the work. The report should explain the problem, classify it as to seriousness, and require an evaluation and correction of the cause of the problem. If the report

classifies the seriousness of each problem, the correction of more important problems can be given priority over less significant problems.

When the system for analyzing the effectiveness of the quality management program is also structured to provide quality trend information, potential problems can be identified and the trend altered before the problem actually occurs. Obviously, this is a more sophisticated technique which permits management to know what areas of work require attention and thereby to prevent defects from occurring. It will also show them the effects of changes that were made to control problem work activities.

APPENDIX A

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